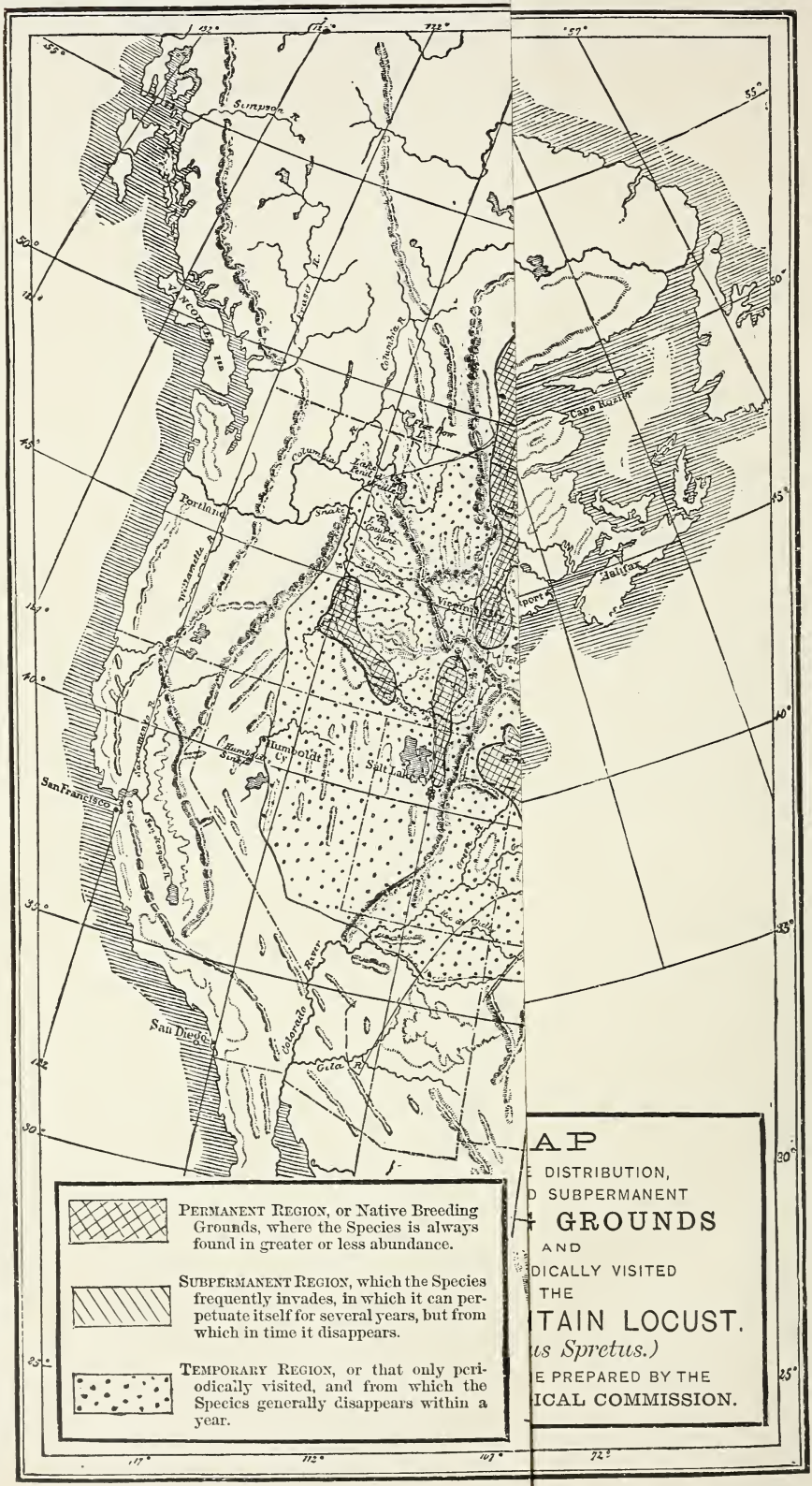

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U. S. DEPARTMENT OF AGRICULTURE.
DIVISION OF ENTOMOLOGY.
BULLETIN No. 25.

DESTRUCTIVE LOCUSTS.

A POPULAR CONSIDERATION OF A FEW OF THE MORE INJURIOUS LOCUSTS (OR "GRASSHOPPERS") OF THE UNITED STATES, TOGETHER WITH THE BEST MEANS OF DESTROYING THEM.

BY

C. V. RILEY, M. A., Ph. D.,
ENTOMOLOGIST.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

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GOVERNMENT PRINTING OFFICE.
1891.


MAP
SHOWING THE DISTRIBUTION,
PERMANENT AND SUBPERMANENT
BREEDING GROUNDS
OF, AND
REGION PERIODICALLY VISITED
BY THE
ROCKY MOUNTAIN LOCUST.
(Caloptenus Spretus.)
REDUCED FROM ONE PREPARED BY THE
U. S. ENTOMOLOGICAL COMMISSION.
PERMANENT REGION, or Native Breeding Grounds, where the Species is always found in greater or less abundance.
SUBPERMANENT REGION, which the Species frequently invades, in which it can perpetuate itself for several years, but from which in time it disappears.
TEMPORARY REGION, or that only periodically visited, and from which the Species generally disappears within a year.
HUDSON BAY
JAMES BAY
San Francisco
San Diego
St Louis
Memphis
New Orleans
Galveston
Dallas
Vicksburg
Mobile
Jackson
Atlanta
Augusta
Charleston
Savannah
Jacksonville
Knoxville
Nashville
Cairo
Springfield
Keokuk
Chicago
Detroit
Toronto
Quebec
Cape Hatteras
Wilmington
Washington
Pittsburg
Denver
Cheyenne
Salt Lake
Santa Fé

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LETTER OF SUBMITTAL.

UNITED STATES DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., March 28, 1891.

SIR: I have the honor to submit for publication Bulletin No. 25 of this Division, being a consideration of a few of the commoner and more destructive locusts of the United States, together with the best remedies to be used against them.

Respectfully,

C. V. RILEY,
Entomologist.

Hon. J. M. RUSK,
Secretary of Agriculture.

DESTRUCTIVE LOCUSTS.

INTRODUCTION.

Since the great "grasshopper years" of 1873–'76 there have been frequent outbreaks of comparatively local species, as well as a few cases in which small swarms of the Rocky Mountain Locust have flown out into the subpermanent region and have occasioned some damage for a year or so. The most notable cases have been the outbreaks of the Lesser Migratory Locust in New Hampshire in 1883 and 1889, the extraordinary multiplication of the Devastating Locust in California in 1885, the increase of local species in Texas in 1887, the multiplication of a chance swarm of the Rocky Mountain species in a restricted locailty in Minnesota in 1888, and last year's damage in Idaho by several nonmigratory species combined.

For a number of years the First and Second Reports of the United States Entomological Commission, which contained the results of the labors of the commission upon the Rocky Mountain Locust, have been out of print, and yet with every renewed alarm caused by locusts there has been a great demand upon this Division for information, which could only be supplied by correspondence or by publishing the information in local newspapers. For a time the demand was filled by supplying the Annual Report of this Department for 1877, which contained bodily the chapters upon remedies from the first commission report. The supply of this document was also soon exhausted.

The fact that Mr. Bruner in his last summer's trip to Idaho investigated the latest rumors and found that considerable damage was being done and that the farmers were not acquainted with even the most rudimentary measures for protection and remedy, shows the necessity of publishing a condensed and practical account of the species which become seriously injurious from time to time, and of republishing in as brief form as possible the matter on remedies and preventives from the reports mentioned. This bulletin is the result. It is, in fact, a reproduction of matter already published but now inaccessible for dissemination, and which, from its nature, has a permanent value, together with such additional facts as subsequent experience has revealed. It contains no technical matter whatsoever, and the farmer will be able to recognize the different species from the figures which accompany the

consideration of each. The portion which relates to remedies, while drawn up for use against the Rocky Mountain Locust, will apply in large part to other migratory locusts, as well as to the non-migratory species. Long, detailed descriptions of the various machines which were given in the original reports are, for the most part, omitted, in the belief that the figures themselves will be sufficiently suggestive for the present purpose. In point of fact, many of these machines, especially the more complicated, while serviceable, cannot be recommended to the average farmer dealing with the locust plague, and experience has shown that those simple forms providing for the use of coal oil and coal tar are, on the whole, the most efficacious against the unfledged insects. It is, therefore, to this portion of the bulletin that I would particularly call the attention of those needing the information contained in it. But little experience of practical value has been had since the last great invasion; hence little has been added to this section of the bulletin beyond a brief description of the trapping system used in Cyprus against the migratory locusts of the Old World, and an account of the bran-arsenic mash remedy used in California in 1885 against the Devastating Locust.

C. V. R.

THE ROCKY MOUNTAIN LOCUST.

(*Caloptenus spretus* Thomas.)

RANGE OF SPECIES.—In the first report of the U. S. Entomological Commission this species has been fully treated, and the region over which it is found divided into the *Permanent*, *Subpermanent*, and *Temporary*

FIG. 1.—*Caloptenus spretus:* Process of acquiring wings: *a*, pupa with skin just split on the back; *b*, the imago extending; *c*, the imago nearly out; *d*, the imago with wings expanded; *e*, the imago with all parts perfect, natural size (after Riley).

regions. These may be briefly explained as follows: *Permanent*, that in which the locust breeds each year and is always to be found in greater or less numbers; *Subpermanent*, that in which it is liable to breed for some years, when it multiplies in excessive numbers in its truly permanent breeding grounds, but from which it in time disappears; *Temporary*, that over which the locusts migrate in years of excessive abundance, but in which they seldom breed and generally disappear within a year. The *Permanent* region embraces the greater part of Montana, a narrow strip of western Dakota, all but the northwestern quarter of Wyoming, the central and northwestern portion of Colorado, a small tract in north central Utah and southeastern Idaho, another similar tract in eastern Oregon and southern Idaho, and a very large area in the British possessions north of Montana which equals more than one-third of the whole region. The *Subpermanent* region lies immediately east of this, taking in a part of Manitoba, nearly all of Dakota, the western half of Nebraska, and the northeastern quarter of Colorado. The *Temporary* region extends to within from 250 to 300 miles of the Pacific coast, then taking in northern Arizona and New

Mexico, all of Texas, Indian Territory, Kansas, Nebraska, western Missouri, the greater half of Iowa, nearly all of Minnesota, besides an additional strip in the British possessions which includes Manitoba and the country north to Lake Winnipeg.

DESTRUCTIVE APPEARANCES.—In Chapter II of the first report of the Entomological Commission the chronological history of this locust is treated at length. We introduce here a short resumé of these appearances:

1818 and 1819. Minnesota and Red River region in Manitoba.
1820. Western Missouri, probably also Kansas and country to north.
1842. Minnesota and Wyoming.
1845. Texas.
1846 and 1847. Wyoming.
1849. Texas and possibly Minnesota.
1851–1872 and 1875–1877. Every one of these years in Utah.
1852. Idaho.
1853. Dakota.
1854. Texas, Kansas.
1855. Texas.
1856. Texas, Kansas, Iowa, Minnesota, possibly Wyoming.
1857. Texas, Kansas, Nebraska, Iowa, Minnesota, Wyoming, Manitoba.
1860. Topeka, Kansas.
1861. Nebraska, Montana.
1862. Montana.
1863. Montana, Dakota, Minnesota.
1864. Montana, Dakota, Colorado, parts of New Mexico, Nebraska, Iowa, Minnesota, Manitoba.
1866. Kansas, Nebraska, northeastern Texas, western Missouri, Iowa, Minnesota, Colorado.
1868–1869. Montana, Idaho, Dakota, Colorado.
1870. Iowa, Minnesota, and slight in Dakota, Idaho, Wyoming.
1872. Slight in Minnesota, Dakota, Montana, Colorado.
1873. Northern Colorado, southern Wyoming, Nebraska, Dakota, southwest Minnesota, northwest Iowa.
1874. Colorado, Nebraska, and Kansas overrun, while parts of Wyoming, Dakota, Minnesota, Iowa, Missouri, New Mexico, Indian Territory, and Texas were ravaged by swarms from Montana and British America where they were abundant. This was the year of the most disastrous invasions.
1875. Portions of Kansas, Nebraska, Missouri; also more or less abundant and destructive from Manitoba to Texas.
1876. Montana, British America, Wyoming, Dakota, Minnesota, Colorado, Kansas, Nebraska, west half of Iowa, west strip of Missouri, Indian Territory, Texas.
1877. Minnesota, Iowa, Dakota, Montana.
1885. Eastern Montana, northwest Dakota.
1888. Minnesota, principally Otter Tail County.

LIFE-HISTORY AND HABITS—*Where the Eggs are laid.*—The eggs may be laid in almost any kind of soil, but by preference they are laid in bare, sandy places, especially on high, dry ground, which is tolerably compact and not loose. It is often stated that they are not laid in meadows and pastures, and that hard road-tracks are preferred; in truth, however, meadows and pastures, where the grass is closely grazed, are much

used for ovipositing by the female, while on well-traveled roads she seldom gets time to fulfill the act without being disturbed. Thus a well-traveled road may present the appearance of being perfectly honeycombed with holes, when an examination will show that most of them are unfinished and contain no eggs; whereas a field covered with grass stubble may show no signs of such holes and yet abound with eggs. In fact, wherever holes are noticed, it may generally be taken for granted that they contain no eggs, for the mother covers well the hole when she has time to properly complete her task.

Furthermore, the insects are more readily noticed at their work along roads and roadsides than in fields; a fact which has also had something to do in forming the popular impression. Newly plowed land is not liked; it presents too loose a surface; but newly broken sward is often filled with eggs. Moist or wet ground is generally avoided for the purpose under consideration.

We have noticed that in the permanent breeding region, wherever the vegetation is scant, the females show a decided preference for the shaded base of shrubby plants, among the roots of which they like to place their eggs; whereas in the temporary region, where the vegetation is generally so much ranker, exposed situations, or those comparatively bare of vegetation, are preferred. The experience of 1876 proved very conclusively, also, that they are instinctively guided toward cultivated fields, where the young will find good pasturage; for the eggs were noticeably thickest and hatched most numerously in 1877 in cultivated areas. In the Cypress Hills region of British America, as Mr. J. G. Kittson informs us, the high lands and protected slopes of the hills are preferred. The soil of the mountain region, where the insects permanently breed, is mostly of a compact, scantily covered, gravelly nature, and the notion that they lay most in pure sand is an erroneous one.

Sandy soil that is compact, especially when having a south or east exposure, is much chosen, but in loose and shifting sand the eggs would perish. In 1876, it was generally remarked that the insects were more indifferent than usual in ovipositing, and that eggs were much more frequently laid in low, and even wet, land than in former years.

The mass seldom reaches more than an inch below the surface, except where some vegetable root has been followed down and devoured, and the insect leaves her eggs before emerging; in this way the mass is sometimes placed a foot below the surface. In abnormal or unhealthy conditions, the eggs may be laid in exposed places without any hole, in which case they doubtless never give birth to young. In other cases, the female will fill her hole almost entirely with the sebific matter. Nor are the eggs invariably laid in the ground, for while we know of no exceptions to this normal position in *spretus*, yet Mr. Boll informs us that around Dallas, Tex., in 1876, the eggs of *differentialis* were very numerously placed under the bark of elm and hackberry logs that had been

felled on low land. We have also received from Mr. A. W. Hoffmeister, of Fort Madison, Iowa, the eggs of a species of *Stenobothrus*, and the young that hatched from them, the eggs having been thrust into holes made by some carpenter-bee in a fence-post; while *Chlöealtis conspersa* habitually bores in dead wood.

Manner in which the Eggs are laid.—The female, when about to lay her eggs, forces a hole in the ground by means of the two pairs of horny valves which open and shut at the tip of her abdomen, and which, from their peculiar structure, are admirably fitted for the purpose. (See Pl. I, Fig. 2, where *b*, *c*, show the structure of one of each of the upper and lower valves.) With the valves closed she pushes the tips into the ground, and by a series of muscular efforts and the continued opening and shutting of the valves she drills a hole, until in a few minutes (the time varying with the nature of the soil) nearly the whole abdomen is buried. The abdomen stretches to its utmost for this purpose, especially at the middle, and the hole is generally a little curved, and always more or less oblique (Pl. I, Fig. 1, *d*). Now, with hind legs hoisted straight above the back, and the shanks hugging more or less closely the thighs, she commences ovipositing.

When the hole is once drilled there exudes from the tip of the body a frothy, mucous matter, which fills up the bottom of the hole and bathes the horny valves. This is the sebific fluid which is secreted by the sebific or cement gland. By repeatedly extricating and studying specimens in every possible stage of oviposition we have been able to ascertain the exact method by which the egg-mass is formed. The process has never been accurately described by other writers, and the general impression—upon which figures like those of Gerstäcker's * are founded—is that the eggs are extruded from between the distended hooks or valves. If we could manage to watch a female from the time the bottom of her hole is moistened by the sebific fluid, we should see the valves all brought together, when an egg would pass down the oviduct (Pl. I, Fig. 3, *j*) along the ventral side, and, guided by a little finger-like style (the *gubernaculum ovi*, *g*), "pass in between the horny valves (which are admirably constructed, not only for drilling but for holding and conducting the egg to its appropriate place), and issue at their tips amid the mucous fluid already spoken of. Then follows a period of convulsions, during which more mucous material is elaborated, until the whole end of the body is bathed in it, when another egg passes down and is placed in position. These alternate processes continue until the full complement of eggs are in place, the number ranging from 20 to 35, but averaging about 28. The mucous matter binds all the eggs in a mass, and when the last is laid the mother devotes some time to filling up the somewhat narrower neck of the burrow with a compact and cellulose mass of the same material, which, though light and easily penetrated, is more or less impervious to water,

* Die Wanderheuschrecke, Berlin, 1876, Taf. II, Fig. 4.

and forms a very excellent protection (Pl. I, Fig. 5, *d*)." When fresh the mass is soft and moist, but it soon acquires a firm consistency.

During the operation the female is very intent on her work, and may be gently approached without becoming alarmed, though when suddenly disturbed she makes great efforts to get away, and extricates her abdomen in the course of a few seconds, the time depending on the depth reached.

The legs are almost always hoisted straight above the back during the process, as shown in the figure (Fig. 1), with the shanks hugging more or less closely the thighs. Sometimes, however, especially when the abdomen is fully buried, the ends of the hind feet may rest firmly on the ground, as has been observed by Dr. Packard in the case of *femur-rubrum*.

The time required for drilling the hole and completing the pod will vary according to the season and the temperature. During the latter part of October or early in November, 1876, when there was frost at night and the insects did not rouse from their chilled inactivity until 9 o'clock a. m., the females scarce had time to complete the process during the 4 or 5 warmer hours of the day; but with higher temperature not more than from 2 to 3 hours would be required.

We have been for weeks with the insects where they were so thickly ovipositing that the light, clay-yellow ground would be darkened by them, and have laid on a closely-grazed sward for hours with specimens in the act all around, and have repeatedly verified all that we have here described.

Philosophy of the Egg-mass.—To the casual observer the eggs of this locust appear to be thrust indiscriminately into the hole made for their reception. A more careful study of the egg-mass, or egg-pod, will show, however, that the female took great pains to arrange them, not only so as to economize as much space as possible, consistent with the form of each egg, but so as to best facilitate the escape of the young locust; for if, from whatever cause, the upper eggs should fail to hatch, or should hatch later than the lower ones, the former would offer an impediment to the exit of the young in their endeavors to escape from these last, were there no provision against such a possibility. The eggs are, indeed, most carefully placed side by side in four rows, each row generally containing seven. They oblique a little crosswise of the cylinder (Pl. I, Fig 4, *a*). The posterior or narrow end, which issues first from the oviduct, is thickened, and generally shows two pale rings around the darker tip (Pl. I, Fig 5, *b*). This is pushed close against the bottom of the burrow, which, being cylindrical, does not permit the outer or two side rows to be pushed quite so far down as the two inner rows, and for the very same reason the upper or head ends of the outer rows are necessarily bent to the same extent over the inner rows, the eggs when laid being somewhat soft and plastic. There is, consequently, an irregular channel along the top of the mass (Pl. I, Fig. 5, *c*), which is

filled only with the same frothy matter that surrounds each egg, which matter occupies all the other space in the burrow not occupied by the eggs. The whole plan is seen at once by a reference to the figure referred to, which represents, enlarged, a side view of the mass within the burrow (*a*), and a bottom (*b*) and top (*c*) view of the same, with the earth which adheres to it removed.

Number of Egg-masses laid by a single Female.—Yersin concludes, referring to the European *migratoria*, that eggs are laid thrice, at intervals of about a month, while Krünitz, Keferstein, and Stoikowitsch† also declare that they are laid in three different masses. Professor Whitman, in his 1876 experiments, had a female which laid about the middle of July, and died September 9, without laying again, though eggs were found in the ovaries at death. The time between the first and second laying, observed by Körte, was 6 days. Mr. Aughey, from experiments made in 1876, found the interval still shorter, ranging from 2 to 3 days; but he requests us to add that other experiments, not recorded, showed a much longer interval between the periods, extending in some cases to 20 days. It would thus appear that there is the greatest diversity in the time intervening between the periods of egg-laying and that the number of egg-masses formed by one individual is by no means constant. It is natural to suppose that there will be great difference in individual prolificacy, and we are also of the opinion that there is great difference in this respect in different generations—those that hatch in the permanent region being more prolific than those which hatch in the temporary region. This opinion is not only warranted by the general experience of farmers, but also by experiment. As compared with those of 1876, the autumn flights of 1877 were for the most part intestate, and it was very generally noticed that they laid no eggs. There is, as we have seen in the preceding chapter, the best of reasons for believing that these flights were not from the permanent region, but consisted mainly of insects that had bred in the temporary region.

It is well known that the reproductive organs are easily affected by any sudden change of climatic conditions which animals may be subjected to, and that sterility is one of the most frequent consequences of such change. It was upon this general rule that the late B. D. Walsh, knowing nothing of the return migration, based the theory that the Rocky Mountain locust could never thrive in the temporary region, but would become intestate and perish there. In 1876 we had measurable success in getting *spretus* to lay eggs in confinement. In 1877, though we made far more strenuous efforts with the insects that hatched in Texas and Kansas, yet we signally failed. Of many thousands which we hatched in St. Louis and endeavored to rear under the most favorable circumstances in vivaria containing growing grain, most of them died in from 3 to 8 days from hatching. We succeeded in bringing a few through the third and two through the fourth molt. At Carbondale, Ill., from

† See Koppen, p. 36.

Minnesota eggs, Mr. Thomas had better luck, and reared several to the winged condition. We repeatedly dispatched living specimens both of the pupæ and the mature insects from Texas, Kansas, and Iowa to our office clerk, Mr. Th. Pergande, St. Louis, but with no more favorable results, as he entirely failed to obtain eggs, and the females, when dead, were found, upon examination, to contain none. This want of fecundity, though not universal, was quite general with the insects of 1877, and is in keeping with the general experience as to the sickly and degenerate nature of the brood.

It is quite manifest, therefore, that in answering the question we have just asked we can do so only in a general and qualified manner. The number of eggs produced by a well-developed locust will range from 100 to 150, if we consider species generally. We have counted 171 in one mass of *Caloptenus differentialis;* from 120 to 130 in those of *Œdipoda phænicoptera*, and about 120 in that of *Acridium americanum*. The great probability is that the eggs of such species are all laid at once. In species like *spretus*, which rarely lay more than 30 eggs in one mass, it were natural to infer that different layings take place, even did the facts at hand not prove such to be the case. In 1876 the insects were pushing continuously southward from the middle of August till the end of October, and during most of this time they were laying eggs. In fact, throughout the country invaded, from Minnesota to south Texas, they continued laying till frost, and we know from examinations that many of them perished before all the ova had been disposed of. Stragglers were even noticed in Texas as late as December.

To sum up the inquiry, we would give it as our belief that the laying season normally extends from 6 to 8 weeks; that it may be shortened or lengthened by conditions of weather and climate; that fecundity is materially affected by the same conditions; that the average number of egg masses formed is three; and that the average interval between the periods of laying by the same female is 2 weeks.

The Hatching Process.—Carefully examined, the eggshell is found to consist of two layers. The outer layer, which is thin, semiopaque, and gives the pale, cream-yellow color, is seen by aid of a high magnifying power to be densely, minutely, and shallowly pitted; or, to use still more exact language, the whole surface is netted with minute and more or less irregular, hexagonal ridges (Pl. 1, Fig. 4, *a*, *b*). It is a mere covering of excreted matter, similar in nature to the mucous or sebific fluid already described, which binds the eggs together. The inner layer (or *chorion*) is thicker, of a deeper yellow, and perfectly smooth. It is also translucent, so that, as the hatching period approaches, the form and members of the embryon may be distinctly discerned through it. The outer covering is easily ruptured, and is rendered all the more fragile by freezing; but the inner covering is so tough that a very strong pressure between one's thumb and finger is required to burst it. How, then, will the embryon, which fills it so compactly that there is scarcely

room for motion, succeed in escaping from such a prison? The rigid shell of the bird's egg is easily cracked by the beak of its tenant; the hatching caterpillar, curled within its eggshell, has room enough to move its jaws and eat its way out; the egg-coverings of many insects are so delicate and frail that the mere swelling of the embryon affords means of escape; those of others are so constructed that a door flies open, or a lid lifts by a spring, whenever pressure is brought to bear; in some, two halves open, as in the shell of a mussel; whilst in a host of others the embryon is furnished with a special structure called the egg-burster, the office of which is to cut or rupture the shell, and thus afford means of escape. But our young locust is deprived of all such contrivances, and must have another mode of exit from its tough and sub elastic prison. Nature accomplishes the same end in many different ways. She is rich in contrivances. The same warmth and moisture which promote the development of the living embryon also weaken the inanimate shell, by a process analogous to decomposition, and by a general expansion consequent upon the swelling of the embryon within. Thus, the eggs when about to hatch are much more plump and somewhat larger and more transparent than they were when laid. At last, by the muscular efforts of the nascent locust, and the swelling of its several parts, especially about the head and mouth, the shell gives way, generally splitting along the anterior ventral part. The whole process may, in fact, be likened to the germination of a hard-covered seed, when planted in moist ground, and, precisely as in this latter case, there is in some loose soils a certain heaving of the ground from the united swelling of the locust eggs. All the eggs in a given mass burst very nearly at one and the same time, and in that event the lowermost individuals await the escape of those in front of them, which first push their way out through the neck of the burrow (Pl. 1, Fig. 4, *d*) provided by the parent.

They all escape, one after the other, through one small hole, which in the field is scarcely noticeable. Such is the usual mode of hatching; but when the young from the lower eggs hatch first, or when the upper eggs perish and leave the lower ones sound—as is not unfrequently the case—the exit is nevertheless easily made along the channel already described (Pl. 1, Fig. 5, *c*).

When once the shell is ruptured the nascent larva soon succeeds, by a series of undulating movements, in working free therefrom and making its way to the light in the manner just described. Once on the surface of the ground it rests for a few minutes, generally lying on the side. Its members are still limp and directed backward, and it is yet enveloped in a very delicate film or pellicle, which must be cast off before the little creature can move with alacrity.

By continuance of similar contracting and expanding movements which freed the animal from the earth, this film in a very short time splits along the middle of the back near the head (strictly the protho-

rax,) and is then worked off behind, and finally kicked from the hind feet in a little white crumpled pellet, that has justly been likened by some of our correspondents to a diminutive mushroom. These little pellets invariably lie close around the hole in the ground from which the young locusts issued. The pellicle begins to split, under ordinary conditions of warmth, within a minute from the time the locust is fairly out of the ground, and is shed in from one to five minutes, according to circumstances. Pale and colorless when first freed from this pellicle, the full-born locust is nevertheless at once capable of considerable activity, and in the course of an hour assumes its natural dark gray coloring. Dr. Packard observed (Report to Dr. Hayden, 1877, p. 634) that specimens which hatched at 11 a. m. began to turn dark at 3 p. m., thus showing that the time may vary; but numerous close observations which we have made on single individuals show that an hour seldom passes after the amnion is thrown off before the gray color is acquired.

From this account of the hatching process, we can readily understand why the female in ovipositing prefers compact or hard soil to that which is loose. The harder and less yielding the walls of the burrow, the easier will the young locust crowd its way out.

Though the covering which envelops the little animal when first it issues from the egg is quite delicate, it nevertheless, in the struggles of birth, undoubtedly affords much protection, and it is an interesting fact that while, as we have just seen, it is shed within a few minutes of the time when the animal reaches the free air, it is seldom shed if, from one cause or other, there is failure to escape from the soil, even though the young locust may be struggling for days to effect an escape.

While yet enveloped in this pellicle, the animal possesses great forcing and pushing power, and, if the soil be not too compact, will frequently force a direct passage through the same to the surface, as indicated at the dotted lines (Pl. I, Fig. 5, *e*). But if the soil is at all compressed it can make little or no headway, except through the appropriate channel (*d*). While crowding its way out the antennæ and four front legs are held in much the same position as within the egg, the hind legs being generally stretched. But the members bend in every conceivable way, and where several are endeavoring to work through any particular passage, the amount of squeezing and crowding they will endure is something remarkable. Yet if by chance the protecting pellicle is worked off before issuing from the ground, the animal loses all power of further forcing its way out. The instinctive tendency to push upward is also remarkable. In glass tubes, in which I have had the eggs hatching in order to watch the young, these last would always turn their heads and push toward the bottom whenever the tubes were turned mouth downward; while in tin boxes, where the eggs were placed at different depths in the ground, the young never descended, even when they were unable to ascend on account of the compactness of the soil above.

Where and under what Conditions of Soil the Young hatch most freely.—The eggs will hatch under the most varied conditions. As a rule, the soils and locations preferred by the female in ovipositing will be those in which the young will most freely hatch, viz, compact and sandy or gravelly knolls and hillsides with a south or southeast exposure.

The experience of 1877 shows also that hatching takes place very freely in late-mown meadows or prairies or grazed pastures, where the exposure of the ground admits of ready oviposition and the warmth of the sun. In dry, well-drained, and compact soils of a light nature the eggs are much better preserved than in heavy clays and loams, where they are more subject to mold and rot. The experience of 1877 is rather misleading on this point, and indicates the necessity of generalizing, not from the experience of one, but of many years. The insects were most numerous, and seemed to hatch most numerously in the lowlands and in sheltered situations along river courses. The facts are, that in such situations those which did hatch survived in larger proportions than did those which hatched in more exposed places, because the former were better protected from the cold rains and storms of spring.

Time of Hatching.—Here, again, we can not take the experience of any one year as a guide, but find the necessity of generalizing from all past experience. In much of the locust area there prevailed such late warm weather in the autumn of 1876 that considerable numbers of the young hatched prematurely; and such is very generally the case. We had also some unseasonably warm weather in January and February, 1877, during which large numbers hatched. These all subsequently perished. During the latter part of March and early in April the hatching was general, but there followed a period of cold, rainy weather, which checked the hatching and destroyed a large number of the insects that had hatched. May and June were characterized by abundant rains and storms, alternating with warm, sunny weather, causing the hatching to be irregular and in some cases quite retarded. It would not be incorrect, therefore, to say that in one and the same neighborhood the hatching commenced on the 1st of February, and did not cease till the end of June, thus covering a period of 5 months. Yet this is exceptional, and it has been much more regular and the period more restricted in previous years.

Those eggs which are laid earliest the previous year will also hatch earliest; and since the egg-laying covers an average period of 6 or 8 weeks in the same locality and lasts generally till frost, it follows that the eggs pass the winter in every stage of development—some with the fluids clear and limpid, others with the embryo fully formed and ready at the first approach of spring to hatch. This we found also to be actually the case, for many hundreds of egg-masses examined during the winter of 1876–'77, from divers parts of the infested region, showed every state of development.

In the same locality hatching will take place—*cæteris paribus*—first

on light dry soils and on south and southeast exposures; latest on low, moist, and shaded or tenacious ground.

We see, therefore, that the hatching will not alone vary according to temperature and the earliness or lateness of the spring, but that it is quite variable under the same conditions. In every instance there will be a few hatching when the first hatched in the same locality are getting wings; and we give it as a general rule that the bulk of the eggs hatch out in the different latitudes about as follows:

In Texas, from the middle to the last of March.

In the southern portions of Missouri and Kansas, about the second week in April.

In the northern parts of Missouri and Kansas and the southern sections of Iowa and Nebraska, the latter part of April and first of May.

In Minnesota and Dakota the usual time for hatching ranges from early in May in the southern portions to the third week in the northern extremity.

In Montana and Manitoba, from the middle of May to the first of June.

In short, the bulk of the insects hatch in ordinary seasons about the middle of March in latitude 35°, and continue to hatch most numerously about four days later with each degree of latitude north, until along the forty-ninth parallel the same scenes are repeated that occurred in southern Texas seven or eight weeks before.

From a number of experiments which we have made on the eggs, we conclude that, with a constant temperature of 85° F., with favorable conditions of soil, the eggs will hatch in from four to five weeks after they are laid, and in a temperature of 75° F. in about six weeks. Dr. Riley has had the eggs of *Caloptenus atlanis* (laid in July) hatched in from three to four weeks; those of *Tragocephala viridifasciata* (laid in June) in three weeks; and those of *Acridium americanum* (laid in July) in rather more than a month.

Habits of the young or unfledged Locusts in the temporary Region.—The habits of the young insects as they occur in the temporary region, and particularly in the country south of the forty-fourth parallel and east of the one hundredth meridian, are as follows: Although possessed of remarkably active powers from the moment they leave the egg, yet so long as provision suffices for them on their hatching-grounds the young remain almost stationary and create but little apprehension. As soon, however, as the supply of food in these situations is exhausted, they commence to migrate, frequently in a body a mile wide, devouring, as they advance, all the grass, grain, and garden-truck in their path. The migrating propensity is not developed until after the first molt, and often not till after the second or third. Up to that time they are content to huddle in warm places, and live for the most part on weeds, and especially on the common Dog-fennel or May-weed (*Maruta*), where it is present.

The young locusts display gregarious instincts from the start, and congregate in immense numbers in warm and sunny places. They thus often blacken the sides of houses or the sides of hills. They remain thus huddled together during cold, damp weather. When not traveling, and when food is abundant, or during bad, rainy weather, they are fond of congregating on fences, buildings, trees, or anything removed from the moist ground. They also prefer to get into such positions to undergo their different molts. In fields they collect at night or during cold, damp weather, under any rubbish that may be at hand, and may be enticed under straw, hay, etc., scattered on the ground. Old prairie-grass affords good shelter, and where a wheat field is surrounded with unburned prairie they will gather for shelter along the borders of this last.

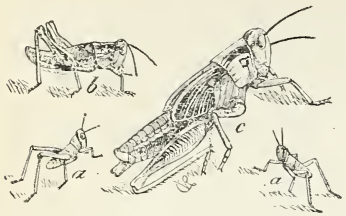


FIG. 2.—*Caloptenus spretus*: *a a*, newly hatched larvæ; *b*, full-grown larva; *c*, pupa, natural size (after Riley).

It is more particularly while they are yet small, or in the first, second, and third stages, that the young locusts hide at night, and, during unfavorable weather, at day also. In windy weather they are fond of gathering and secreting under any shelter, or in crevices and inequalities of the soil. At such times farmers too often conclude that the pests have perished and vanished; but a few hours of pleasant, sunny weather will bring the insects to sight again and dispel the delusion. When very vigorous and numerous they gradually move across a field of small grain and cut it off clean to the ground as they go, appearing to constantly feed. But when diseased or sickly, as in 1877, they gather in bare and sunny spots and huddle and bask without feeding. The very cold, wet weather that is prejudicial to them is beneficial to the grain, and under such circumstances it generally grows so rank and rapidly that they make little impression upon it.

It is when they are abundant and vigorous enough to bare the ground of vegetation, and this principally after they are half-grown, that the habit of migrating in large bodies is developed. In 1877 scarcely any disposition to migrate was shown, and this was in strong contrast with what occurred in 1875. In a year like this last, when they are vigorous and abundant, their power for injury increases with their growth.

At first devouring the vegetation in particular fields and patches in the vicinity of their birthplaces, they gradually widen the area of their devastation, until at last, if very numerous, they devour every green thing over extensive districts. Whenever they have thus devastated a country they are forced to feed upon one another, and perish in immense numbers from debility and starvation. Whenever timber is accessible they collect in it, and after cleaning out the underbrush, feed upon the dead leaves and bark. A few succeed in climbing up into the

rougher barked trees, where they feed upon the foliage, and it is amusing to see with what avidity the famished individuals below scramble for any fallen leaf that the more fortunate mounted ones may chance to sever. This increase in destructiveness continues until the bulk of the locusts have undergone their larval molts and attained the pupa state. The pupa, being brighter colored, with more orange than the larva, the insects now look, as they congregate, like swarms of bees. From this time on they begin to decrease in numbers, though retaining their ravenous propensities. They die rapidly from disease and from the attacks of natural enemies, while a large number fall a prey, while in the helpless condition of molting, to the cannibalistic proclivities of their own kind. Those that acquire wings rise in the air during the warmer parts of the day and wend their way as far as the wind will permit toward their native home in the Northwest. They mostly carry with them the germs of disease or are parasitized, and wherever they settle do comparatively little damage.

Directions in which the young Locusts travel.—The young insects when migrating move, as a rule, during the warmer hours of the day only, feeding, if hungry, by the way, but generally marching in a given direction until toward evening. They travel in schools or armies, to no particular or constant point of the compass, but purely in search of food—the same school one day often pursuing a different course from that pursued the day previous. On this point the experience of 1875 as well as of 1877 is conclusive, though the bulk of the testimony as to their actions, when hatching out in the more northern States, is to the effect that the prevailing direction taken is south or southeast, while in Southern Texas it is just opposite, or north. A person traveling along a road may often see one army marching in one direction to the left and another in the opposite direction to the right, and we have repeatedly had such an experience.

If, from any reason whatsoever, the vanguard of a column changes its course, the changed direction is in some way communicated in wave-like form to those in the rear. Usually, the front of a column is not easily diverted, however, but will pass through such obstacles as open fences rather than change course. Sometimes two schools going in different directions will cross each other, the individuals of either keeping to their particular course and presenting a singular spectacle as they hop past one another.

It is recorded in Europe that few things, not even water, stop the armies of the young locusts when on the march, and Döngingk relates having seen them swim over the Dniester for a stretch of $1\frac{1}{4}$ German miles, and in layers 7 or 8 inches thick.* We have had similar experience with our own species. In 1875, near Lane, Kans., they crossed the Pottawatomie Creek, which is about 4 rods wide, by millions; while

* Köppen, *loc. cit.*, p. 43.

the Big and Little Blues, tributaries of the Missouri, near Independence, the one about 100 feet wide at its mouth and the other not so wide, were crossed at numerous places by the moving armies, which would march down to the water's edge and commence jumping in, one upon another, till they would pontoon the stream, so as to effect a crossing. Two of these mighty armies also met, one moving east and the other west, on the river bluff, in the same locality, and each turning their course north and down the bluff, and coming to a perpendicular ledge of rock 25 or 30 feet high, passed over in a sheet apparently 6 or 7 inches thick, and causing a roaring noise similar to a cataract of water. (Riley's Eighth Report, p. 118.)

The experience of correspondents as to the movements of the young is very conflicting, as it naturally would be from what we have already said. One man will notice the insects moving with the wind, and conclude that it is the rule for them to do so; another, against the wind, and draw an opposite conclusion.

Rate at which the Young travel.—When about half-grown they seldom move at a greater rate than three yards a minute, even when at their greatest speed over a tolerably smooth and level road, and not halting to feed. They walk three-fourths this distance and hop the rest. Two consecutive hops are seldom taken, and any individual one may be run down and fatigued by obliging it to hop ten or twelve times without a rest.

According to Sydow, the young of the European *P. migratorius* travel, when at their most rapid gait, a German mile in four hours. Even taking the shortest German mile, or nearly four English miles, we very much doubt the accuracy of this statement, for though the *migratoria* is a larger species than *spretus*, we can not believe that it travels nearly ten times as fast, and we have again and again timed our own species.

They reach, in the temporary Region, but a few Miles east of where they hatch.—At the rate at which they travel, as just described, they could not extend many miles, even if they continued to travel in one direction from the time of hatching until maturity. They travel, on an average, not more than 6 hours per day; and their unfledged existence terminates in from 6 to 8, say 7, weeks. It is very easy to calculate from these facts that if they continued in one direction from the time they hatch until they acquire wings, they could not extend 30 miles. In reality, however, they do not travel every day; and where food is abundant they scarcely travel at all.

Moreover, as we have just shown, the migratory propensity is seldom manifested during the first or second larval stages, and it is, in fact, largely dependent on conditions of health and vigor of the insects and on the amount of food supply. We have learned of no cases where the young have extended, during growth, 10 miles east of the hatching limit.

As experience abundantly proves, the insects, when they get wings

in the temporary region, especially in early summer, instinctively fly to the north or northwest, and do not extend to do damage farther east. Those, also, which acquire wings later in the summer in more northerly regions, and which fly more to the south, never extend any great distance east of where they hatch; those developing on the eastern confines of the species' range (see map) passing southwestwardly, and those

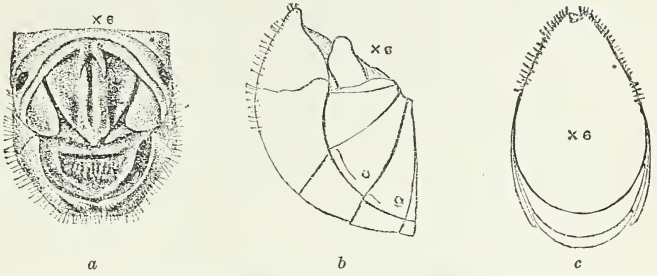


FIG. 3.—*Caloptenus spretus*, anal characters of male; *a*, from above; *b*, from the side: *c*, from below; enlarged six times (Emerton *del*).

born toward the mountains southeastwardly. In 1875, a few stragglers were carried as far as the center of Missouri, by being swept into the Missouri River, and drifting on logs and chips during the annual rise in July. But whenever scattering individuals are carried in this or any other way beyond the eastern limits we have laid down, they soon perish. Most of them are diseased or disabled, and if they lay eggs, these hatch in the autumn and perish at the approach of winter.

Rate at which Locust Swarms move.—The rate of migration of the winged insects will depend entirely on circumstances. The history of the past years of invasion shows conclusively that the rate of progress of invading swarms from the permanent breeding-places will average about 20 miles a day. It is, however, exceedingly irregular and greatly dependent on the velocity of the wind. Bad weather may impede or adverse winds divert flight.

One noticeable feature of the invasions is the greater rapidity with which the insects spread in the earlier part of the season, while in fullest vigor, and the reduction in the average rate of progress the farther east and south they extend. The length of their stay depends much upon circumstances. Early in the summer, when they first begin to pour down on the more fertile country, they seldom remain more than two or three days; whereas, later in the season, they stay much longer. In speaking of the advent and departure of these insects, I use relative language only. The first comers, when—after having devoured everything palatable—they take wing away, almost always leave a scattering rear guard behind, and are generally followed by new swarms; and a country once visited presents for weeks the spectacle of the insects gradually rising in the air between the hours of 9 or 10 a. m. and 3 p. m., and being carried away by the wind, while others are constantly dropping.

In short, the rate of spread is greatest during the first 10 or 15 days of their winged existence, or before the females become occupied with egg-laying. The invading insects are then passing the extensive plains and thinly settled regions of the Northwest, where there is little inducement for them to halt, and the rate at such times, with strong and favorable wind, may reach a maximum of from 200 to 300 miles a day.

The rate of spread of departing swarms from the temporary region is very much the same. It is most rapid and direct early in the season when the insects first begin to leave more southern latitudes, and becomes more slack and inconstant as summer advances.

Extended flight does not take place till 4 or 5 days after the first insects become winged. For the first 2 or 3 days the newly-winged individuals mingle with the larvæ and pupæ, eating ravenously and making short flights of a few yards or more, as if to try their wings, recalling fully the habit of native nonmigratory species. Then for a while they rise one by one higher in the air and float along with the wind, and finally, when weather and wind are favorable, all that are strong and mature enough rise as with a common impulse during the warmer morning hours and move off vigorously in one direction until they are soon out of sight. They begin to rise when the dew has evaporated, and generally descend again toward evening. A swarm passing over a country yet infested with the mature insects constantly receives accretions from these, and is, consequently, always more dense in the afternoon than in the forenoon. In rising the insects generally face the wind, and it is doubtful if they could ascend to any great height without doing so.

The velocity of flight, which, for many reasons, is quite distinct from the general movement understood by "rate of spread" or "migration," is naturally greater and will average about 10 miles an hour. It is also greatly dependent on the wind. Mr. S. S. Clevenger, of New Auburn, Minn., gives the average rate at 15 miles for that locality; while the reports of other correspondents give the range from 4 to 40 miles, the more common rates mentioned being 12, 15, and 20 miles per hour. Mr. Brown Lusted, of Winnipeg, Manitoba, tells us that in 1867, when he was traveling from Saint Cloud, Minnesota, to Manitoba, the locusts were moving in the same direction, at from 30 to 35 miles a day. Professor Aughey's observations for 1877 give the rate per hour at 4 miles and upward; but he has himself expressed to us the belief that his estimates are somewhat low. We have ourselves never witnessed them flying so slowly as 4 miles per hour, which must be considered the minimum rate where there is no impediment. When tacking against the wind, they may move not more than 1 mile, while the maximum rate, in a strong wind, may reach as high as 50 miles or more per hour.

Direction of invading Swarms.—While there may be, during an invasion, local flights in all possible directions (except, perhaps, due west), the general movement east of the mountains is conspicuously toward

the south and southeast. The more local and irregular flights are generally made for food, but the more extended southward movements are in obedience to other laws, discussed in Chapter XII of the Report and also on page 250. West of the main Rocky Mountain range the rule of flight appears to be from the higher plains and plateaus, where the insect normally breeds, to the lower and more fertile valleys; and the greater irregularity of the prevailing winds and more broken nature of the country preclude the same regularity in directions of flight that, on the whole, prevails east of the range.

Time of Appearance of invading Swarms.—In endeavoring to deduce general conclusions respecting the time of year that the 1874 swarms reached different parts of the country, great difficulty was experienced in sifting those accounts which referred to the progeny of the 1873 invasion, and those which hatched within the insect's native range, and came from the extreme Northwest. The same was true of the fresh 1876 swarms, and those which hatched in Minnesota.

As a rule, the insects which hatch in the temporary region acquire wings and leave before the fresh swarms from the mountain region appear. In the more northern regions, as in Minnesota and Manitoba westward, the insects hatched on the ground acquire wings the latter part of June and in July. The period is earlier as we go south, until in southern Texas they are able to fly in April. The time of appearance of invading swarms from the permanent region is in inverse ratio, *i. e.*, earlier to the north and later to the south. Thus while on the confines of the permanent region it is almost impossible to distinguish between the insects which hatch there and the fresh swarms from the Northwest, the difference becomes more and more marked toward the south and east.

In 1874, swarms appeared during June in southern Dakota; during July in Colorado, Nebraska, and Minnesota; during the latter part of this month in Iowa and western Kansas. During August they came into southeast Kansas and Missouri; and by the middle of October they reached Dallas, in Texas. In 1876 they came later.

Number of Broods.—Peculiarities of Habit.—The Rocky Mountain Locust, in spite of the fact that a second lot of eggs is sometimes deposited in one season, is essentially single-brooded. This second deposition of eggs generally fails to hatch and arrive at maturity in time to reproduce the species. This follows from the fact that this locust is a sub-boreal insect and attains its greatest perfection only where the winters are long and cold and the summers short. The theory has been advanced that the object of the migrations of this species is to find a suitable region for producing a second brood; for instance, that a brood hatched early in the south moves to the northern limits of its range and brings forth a second brood. But it is a notable fact that in years of disastrous invasion from the northwest in late summer and autumn the locusts have not prevailed in the south during the spring.

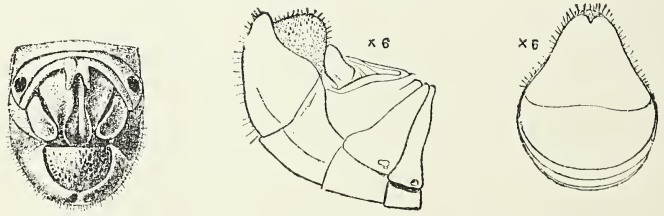
Also in years when they hatch and prevail in the temporary region their migration therefrom in early summer is virtually complete and no disastrous incoming swarms visit the same region later in the season. Single-broodedness is then the rule. Where the species has been observed to breed for 2 or 3 consecutive years, as in Minnesota and northerly regions, only one annual generation is produced. Those swarms which reach Manitoba from the south in early summer lay eggs the bulk of which remain unhatched till the following spring. The same was observed in Minnesota in 1873, the eggs laid that year remaining mostly unhatched until 1874. This rule may have exceptions. Many insects are single-brooded at the northerly limit of their range, but double-brooded farther south, and the premature hatching of the eggs of this locust in autumn in southerly regions is a step in this direction. But it has been conclusively shown that it can not establish itself under more southern climatic influences which suit some of its related species, but can breed permanently only under those conditions which induce single-broodedness.

Hibernation.—From the facts just stated it will be seen that the normal hibernation is passed in the egg state. Though many Acridiidae hibernate in the imago or even the pupa state, under bark, logs, or stones, the species under consideration after laying its eggs in the summer lasts until autumn, but dies with the approach of cold weather.

THE LESSER MIGRATORY LOCUST.

(*Caloptenus atlanis* Riley.)

Range of Species.—*C. atlanis*, in common with the next species, *C. femur-rubrum*, has a very extended natural range, breeding annually in abundance from middle Florida nearly to the Arctic circle, in many places entirely replacing the latter species. It becomes less common



a *b* *c*

Fig. 4.—*Caloptenus atlanis*, anal characters of male; *a*, from above; *b*, from side; *c*, from above, enlarged six times (after Riley).

towards the Mississippi, *C. femur-rubrum* generally predominating, while it gives way to *spretus* on the great plains. It, however, rather strangely, considering that it is essentially an eastern species, again appears toward the Pacific in the more northern regions extending from about the fortieth parallel in Utah and California as far north as the Yukon River.

Destructive Appearances.—In our annual report for 1883 we gave a full historical account of the destructive appearance of this species, and to this account those who are interested are referred. They have been reported as injurious in 1743, 1746, 1749, 1754, 1797, 1798, 1816, 1821, 1826, 1871, 1872, 1874, 1875, 1877, 1882, 1885, and 1889, in one and another locality in New England. The 1885 appearance was described in the report mentioned, and that of 1889 is treated in *Insect Life*, Vol. II, pp. 66–70. Mr. Bruner, in 1885, found the species numerous about Glendive, Montana, and in many places in the region of the Yellowstone and Missouri Rivers it was twice as numerous as *spretus*.

Life-history and Habits.—The following is from the report for 1885.

In general life history it is in all respects similar to *C. spretus*. It will be unnecessary, therefore, to give here anything beyond the most salient facts.

The eggs and the egg mass are so similar to those of *C. spretus* that there is no other difference than in the somewhat smaller size of either. They are laid just beneath the surface of the ground in precisely the same manner. Each female in the course of her life usually deposits two of these masses, though at St. Louis I have observed instances in which three and even four were placed by the same female. It is in the egg state that the insect passes the winter and the young locusts hatch in the spring. The average period between hatching and maturity we found at St. Louis to be 80 days, or some 10 days longer than in the case of *C. spretus* and *C. femur-rubrum*, but in New Hampshire it is probably somewhat longer.

In about one week after reaching full growth the insects pair, and soon thereafter commence ovipositing. There is undoubtedly but one annual generation in New England, whereas in Missouri we found uniformly two. In the Merrimac Valley the hatching period extends throughout May, and most of the individuals have become winged by the early part of July. Oviposition continues from the latter part of July till frost. Some of the earlier laid eggs hatch in autumn, so that there is the same tendency toward a second brood as we find in *spretus*, a tendency which is more marked during a warm, protracted autumn, and which is beneficial to the farmer, inasmuch as all these autumn-hatched individuals invariably perish during the winter.

THE NON-MIGRATORY RED-LEGGED LOCUST.

(*Caloptenus femur-rubrum* Harr.)

Range of the Species.—This locust has a common range with the preceding species. It breeds from Florida to British America, but is more scarce in the eastern portion of its range while it becomes abundant in the Mississippi Valley. *C. femur-rubrum* is also found with *atlanis* on the Pacific Slope.

Destructive Appearances.—Under this head it can only be said that this locust, being non-migratory, causes only local damage, and few

Fig. 5.—*Caloptenus femur-rubrum*—natural size (after Riley).

cases of destructive appearances are to be found recorded. It often increases so as to cause local damage and is yearly more or less abundant throughout its range. In company with the Differential and Two-striped Locusts it frequently gives cause for alarm by devastating grass lands or growing crops. In 1885 it was abundant, with *atlanis*, *spretus*, and local species, about Glendive and in other portions of eastern Montana. In August, 1888, it had, with *bivittatus*, destroyed the oat crop about St. James, in Manitou County, Michigan. Such isolated reports as these come in nearly every year and only show that the species is not capable of concerted damage over any large area.

Life-History and Habits.—These differ little from those of the foregoing species. The female has occasionally been noticed to lay four different egg masses. The period between hatching and maturity was observed at St. Louis to be about 70 days. The species was observed to become winged there about the last of August, and eggs were deposited about the first of October. It is single-brooded.

THE CALIFORNIA DEVASTATING LOCUST.

(*Caloptenus devastator* Scudd.)

Range of the Species.—Scudder records this species as found in California, Nevada, and even sparingly in Colorado. It is, however, essentially a Pacific coast species and is probably to be held accountable for much of the damage attributed in this region to other species. Bruner also records it from the Upper Yellowstone Valley.

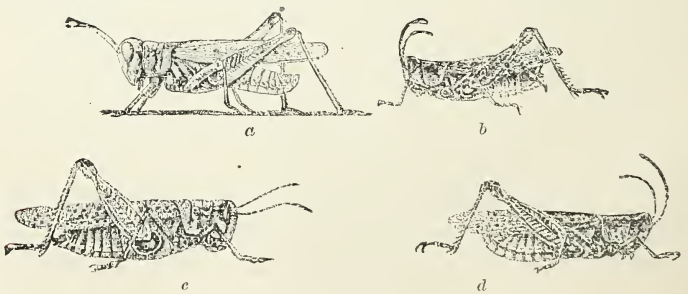


Fig. 6.—*Caloptenus devastator*: *a*, large female from California, 1885; *b*, small female, Reno, Nevada, 1880; *c*, male, Fort Keogh, Montana, 1880; *d*, same as *c*, all natural size (after Riley).

Destructive Appearances.—California has in former years had its locust plague. Many devastating swarms visited the Pacific coast region during the latter half of the last century and the first half of the present, while for 30 years after this period no general destruction was committed. But there is no means of positively identifying these devastations with the species that committed them. The accounts are old, and no descriptions or specimens have been preserved. We can only judge from such later appearances as have furnished us with exact data. It

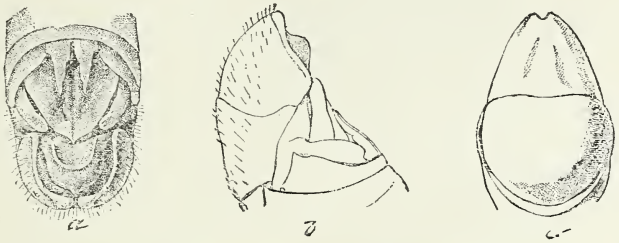


Fig. 7.—*Caloptenus devastator*: anal characters of male; *a*, from above; *b*, from side; *c*, from below—enlarged (after Riley).

is most probable that *C. devastator*, as intimated by Scudder, committed a large, if not the larger, share of these depredations. Accordingly we will, under this species, notice the destructive California appearances, which we give in brief from the first commission report. *Camnula pellucida*, another destructive California species, which is noticed further on, doubtless also assisted in many of these invasions.

In 1722, 1746, 1749, 1753, 1754, 1765, 1767 it appeared in California. (Mr. A. S. Taylor, Smithsonian Report, 1858.) The following, up to 1885, are from the same authority (*l. c.*)

1823. Franciscan Missions of Upper California.
1827 or 1828. "Ate up nearly all the growing crops."
1834 or 1835. "Destroyed the crops of the rancheros and missions, with the exception of the wheat."
1838–1840. For these three years destroyed the crops and gardens about San Francisco and San Rafael.
1846. Corn and frijoles completely consumed on the Salivas Plains. This was a dry year in California.
1852. Near Centreville, Alameda County, California, also in Oregon. They were noticed in the same locality every year since up to 1877, but in very moderate numbers. (Lorenzo G. Yates.)
1855. The most noted year for 10 years on the Pacific coast.—California, Oregon, and Washington Territory. Great damage and many immense flights witnessed in this region.
1856. Lower California small numbers.
1859. Pitt River Valley, California.
1862 or 1863. Horintos, California.
1866 or 1867. Swarm 15 miles wide seen near Stockton, California.
1869. Tulare County, California.
1873. Lower and south California.
1877. Fresno County, California.
1885. San Joaquin Valley of northern California; southern Oregon.

This invasion is known to be due to *C. devastator*, which outnumbered all other species combined in proportion of 7 to 1. The next in abundance was the ash-colored locust, which was only one-twentieth as numerous as the former. Mr. Coquillett's account of this year's invasion is to be found in Annual Department Report for 1885. Mr. Koebele also gives an account in the same report on the locusts about Folsom, California, in 1885, the greater part of which belonged to this species.

LIFE-HISTORY AND HABITS.—The habits of this locust are much the same as those of the preceding species. We have few exact data on this point. The locusts have been found mature and in force early in June. They are generally much more abundant in the foothills along the sides of valleys, and it is probable that these are their usual breeding places. It seemed evident from the 1885 investigations that the locusts did not migrate from a distance, but bred in the vicinity of the plantations; for while the edges of these during the first part of the invasion were well stocked with locusts, there were only a few in the center. Young locusts which were referred to this species were found in some numbers upon uncultivated lands bordering plantations. These waste places are covered with water during the winter, and sometimes until late in summer. When seeding time arrives, they are too wet to be plowed and seeded and thus remain undisturbed. The green vegetation of these waste places furnishes food to the locusts late in the season, when other fields are bare, until the egg-laying season arrives. The subsequent submersion through winter does not seem to affect the vitality of the eggs.

THE DIFFERENTIAL LOCUST.

(*Caloptenus differentialis* Thos.)

RANGE OF THE SPECIES.—This locust ranges through Illinois, Missouri, Nebraska, Kansas, and Iowa. It is also found in Indiana, Texas, New Mexico, and California.

DESTRUCTIVE APPEARANCES.—This and the following species are much larger than the preceding ones, and though like *C. femur-rubrum* they do not possess the migratory habit, they can and occasionally do

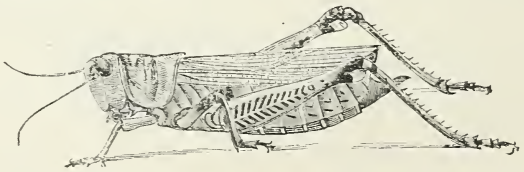


FIG. 8.—*Caloptenus differentialis*, natural size (after Riley.)

make considerable flights. We have devoted some space in the first report of the commission to accounts of damage by this species. It was abundant in 1875 in central Illinois and attracted considerable attention. It was accompanied by the Red-legged and Lesser Migratory

Locusts. In 1877 it became abundant in a restricted locality near Socorra, New Mexico, and in 1885 this species was noticed rather abundantly in company with the Devastating Locust in the San Joaquin Valley in California, occuring in about the proportion of one Differential Locust to twenty-five Devastating Locusts.

Life-history and Habits.—In the vicinity of St. Louis, Missouri, the first specimens of this locust were observed to become winged July 19. Eggs were laid September 9. As a deviation from the usual egg-laying habits of the genus, it is an interesting fact that the eggs are sometimes very numerously placed under bark of logs that have been felled on low land. The eggs of this species, unlike those of *spretus*, *atlanis*, and *femur-rubrum*, are not quadrilinearly but irregularly arranged. This irregular arrangement also occurs in the egg-masses of *Schistocera americana* and *Oedipoda phanæcoptera*. The head ends of the eggs in the pods point mostly outward. One hundred and seventy-one eggs have been counted in a single mass.

Mr. Coquillett has made some interesting observations on the life history and habits of this species, which will be found in the 1885 report. They acquired wings from the last week in June to the last week in July, and began laying eggs July 23. A single female occupied 75 minutes in depositing an egg mass. The situation chosen for egg-laying was invariably the edge of one of the basin-like hollows at the foot of a tree. This locust is not easily startled, and its ordinary flight is rather heavy, and sustained only for a distance of 12 to 20 feet. Mr. Coquillett found it principally in trees, and it seemed to be particularly fond of the leaves of the poplar. He did not find it in grain fields, but it was numerous in fields of alfalfa. Mr. Webster has noticed this insect gnawing the limb of an apple tree at Princeton, Ind.

THE TWO-STRIPED LOCUST.

(*Caloptenus bivittatus* Scudd.)

Range of Species.—This species has a very extended range, being found from Maine to Utah and California and extending as far South as Carolina, Mississippi, and Texas.

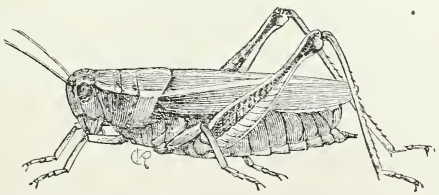


Fig. 9.—*Caloptenus bivittatus*, natural size (after Riley.)

Destructive Appearances.—This locust is distinguished from the last-named species in having two lateral yellowish stripes from the head

to the extremities of the wing covers. (Fig. 9.) Like the last, it sometimes assists in migratory flights with *C. atlanis* and *C. femur-rubrum*. It often becomes locally abundant enough to do much damage to crops. In 1877 Mr. Theo. M. Finley, writing from Niles, Michigan, sent us specimens with the statement that they did considerable damage near Berrien Springs, Michigan, though confined to a territory of only a mile square. Grass and oats suffered most, the last crop being entirely destroyed. At Fort Wallace, Kansas, in July 1877, this locust was common while *C. spretus* was rare. Other occasional cases of damage have been reported, but these are only local occurrences. It does not increase in sufficient force to spread over any large tract of country.

LIFE HISTORY AND HABITS.—We have observed this locust pairing in Missouri from the 8th of July to the 18th of August. The first winged insects were noticed July 7. Females were confined in cages through July and August, but no eggs were deposited until August 31. Eggs kept indoors hatched the last of December.

Those kept outdoors began to hatch the middle of March. A gravid female opened in September was found to contain 79 eggs.

THE PELLUCID LOCUST.

(*Camnula pellucida* Scudd.)

RANGE OF SPECIES.—Synonym: *Œdipoda atrox*. It occurs in California, Utah, Wyoming, Colorado, New Mexico, Montana, Dakota, and in the East in Maine, Massachusetts, Vermont, Connecticut. These Eastern and Western forms were formerly supposed to be two distinct species, the name *atrox* being applied to the Western specimens and *pellucida* to the Eastern; but they have been found to show no appreciable differences, and must be considered the same species.

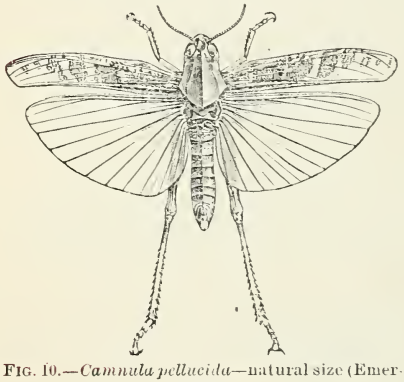


FIG. 10.—*Camnula pellucida*—natural size (Emerton *del*).

DESTRUCTIVE APPEARANCES.—Some of the destructive locust years tabulated under *Caloptenus devastator* may have been due to *Camnula pellucida*, as the two species have doubtless been confused in these invasions. This species, however, is known definitely to have occurred in devastating migratory swarms in California in 1878, particularly in the Sierra Valley, and deposited its eggs by millions on ranches hitherto unvisited by them, thus menacing an immense area of country.

In the previous year, 1877, they ravaged the California coast from Point Conception to Santa Barbara. In 1879 they were again abun-

dant, the numerous eggs deposited in 1878 having developed still greater swarms.

In 1885, according to Bruner, it had become very numerous in the Yellowstone and upper Missouri Valleys, having developed in numbers very rapidly in the preceding 5 years. In this year, in company with *C. spretus* and *C. atlanis*, it did the principal injury in this region to vegetables and grain, while the other native species attacked the grasses.

Life-history and Habits.—This is the only North American locust of the subfamily to which it belongs (*Œdipodinæ*) that is migratory. All the other locusts mentioned in this bulletin belong to another subfamily (*Acridiinæ*). This locust is not a truly migratory species, as its swarms do not rise to a great height or remain long in the air, but has rather assumed the migratory habit in comparatively recent times. Eggs received from California hatched in large numbers the last of April and again in May.

THE AMERICAN ACRIDIUM.

(*Schistocerca americana* Scudd.)

Range of Species.—This is much larger than any of the preceding species, being in fact our largest locust, often measuring more than 2½ inches in length. It occurs throughout the Southern States from the District of Columbia to Texas, and extends south through Mexico into Yucatan and Central America. It is also found as far north as Illinois and Indiana, and is doubtfully reported from New York.

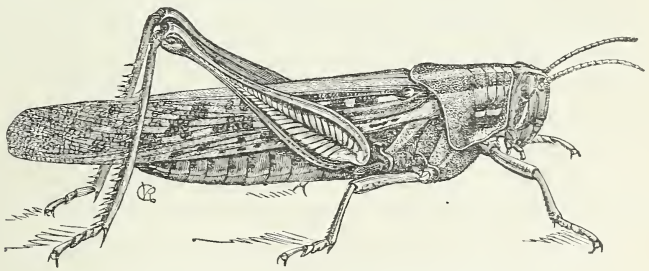


Fig. 11.—*Schistocerca americana*—natural size (after Riley).

Destructive Appearances.—This species was very abundant in 1876 in Missouri, Tennessee, Indiana, Ohio, North Carolina, Georgia, and swarm seven reach Virginia. They caused much devastation, devouring in many places every green thing, even alighting on trees, and caused much alarm. They were supposed to be the Western species (*spretus*) advancing east. They present a more imposing appearance, from their great size, than the Rocky Mountain species, but can not cause such great destruction, as they are generally sedentary within the bounds of the United States, while to the south, in Yucatan and other parts of Central America, they are said to possess the true migratory habit.

LIFE-HISTORY AND HABITS.—I have found the eggs deposited June 24, and obtained the newly hatched larvæ July 27. The arrangement of the eggs is somewhat different from those of other Acridiinæ which have come under my observation, being arranged in such a manner that the head of all the eggs is directed towards the inner or concave side of the pod. They have nearly the same shape as those of *spretus*, are of about the same color, though larger in size and sparsely covered with a crimson cement which binds them together. The pod is about 1½ inches in length by three-eighths of an inch in diameter and nearly straight. The spongy top of the pod is yellowish white. In one of these pods 120 eggs have been counted. They are usually deposited in grassy plots and the average time between hatching and maturity is about 70 days.

REMEDIES AND DEVICES FOR THE DESTRUCTION OF LOCUSTS.

The matter which follows, although originally prepared with reference only to the Rocky Mountain Locust (*Caloptenus spretus*) will apply almost equally well to the other species mentioned in the preceding pages. As applying to the Rocky Mountain Locust the means recommended for its destruction will apply more especially to the Temporary region, while the suggestions as to prevention apply to the Permanent region, and the reader will readily determine which of the means mentioned are applicable to the local or non-migratory species.

The means to be employed fall very naturally into five divisions: (1) Encouragement of natural agencies. (2) Destruction of the eggs. (3) Destruction of the young or unfledged insects. (4) Destruction of the mature or winged insects. (5) Preventive measures.

ENCOURAGEMENT OF NATURAL AGENCIES.

While little practically can be done by man to further the multiplication of the more minute enemies of the locust, much may be done to protect and to promote the multiplication of the larger animals, especially the birds. These should be protected by most stringent laws, firmly carried out, restraining the wanton destruction too often indulged in by sportsmen and others. Some of the states interested in this question have of late years passed good laws for the protection of these feathered friends, but the laws are, unfortunately, too often a dead letter for want of enforcement. One of the most effectual and successful ways of protecting and encouraging many of the smaller birds is to offer a reward for hawks. This has been done with very beneficial results in Colorado, and other states would do well to follow her example.

DESTRUCTION OF THE EGGS.

The destruction of the eggs has been followed, in the older countries of the East, since Pliny's time, and has long been recognized in Europe and Asia as one of the most efficacious means of averting locust injury. These eggs are laid in masses, just beneath the surface of the ground, seldom to a depth of more than an inch; and we have already considered the character of soil and the sites preferred by the females in laying them. In years like 1874 and 1876 we have known favorable locations, for many hundreds of square miles, so thickly supplied with these eggs, that scarcely an inch of the soil could be stirred without exposing them. As a rule, the dead bodies of the locusts strewn about the ground in autumn are a good indication of the presence of eggs in such ground, though the eggs may often be abundant without this indication. The means to be employed in destroying locust eggs may be considered under the following divisions: (1) Harrowing; (2) Plowing or spading; (3) Irrigation; (4) Tramping; (5) Collecting.

(1) Harrowing in the Autumn.—Harrowing in the autumn, or during dry, mild weather in early winter, will prove one of the most effectual modes of destroying the eggs and preventing future injury, wherever it is available. It should be enforced by law whenever the soil in any region is known to be abundantly stocked with eggs. A revolving harrow or a cultivator will do excellent service in this way, not only in the field, but along roadways and other bare and uncultivated places. The object should be, not to stir deeply, but to scarify and pulverize as much as possible the soil to about the depth of an inch. Where the cultivator is used, it would be well to pass over the ground again with a drag or a brush harrow for this purpose. Some of our correspondents have urged, and with some reason, that wherever land can conveniently be prepared to induce the females to oviposit in it, as by plowing and then rolling when the insects are beginning to breed, such preparations should be made. A subsequent harrowing will be the more easy. In practice, this method will not often be adopted, because it will pay only under exceptional circumstances.

(2) Plowing.—Next to harrowing this is one of the most generally available means possessed by the farmer of dealing with locust eggs.

The actual experience is somewhat conflicting, and in some light, dry soils a good number of them will hatch late if turned under a foot; yet, from our own observations, and a vast amount of experience gathered together, we recommend it as profitable. If delayed till spring, it should be done just as the young begin to hatch, as it is then most effectual. The plowing will be effectual according as the soil is porous or tenacious, *and according as the surface is afterward compressed by harrowing and rolling.* From the experiments recorded in the first report of the commission, it is obvious that, all other things being equal, a plowing of 4 to 6 inches will prove more effectual in spring, if the ground be

subsequently harrowed and rolled, than deeper plowing with no subsequent comminution and compression.

(3) Irrigation.—This is feasible in much of the country subject to locust ravages, especially in the mountain regions, where, except in exceptionally favorable locations, agriculture can be successfully carried on only by its aid, and where means are already extensively provided for the artificial irrigation of large areas. Where the ground is light and porous, prolonged and excessive moisture will cause most of the eggs to perish, and irrigation in autumn or in spring may prove beneficial. Yet the experiments recorded in the commission reports prove that it is by no means as effectual as had been generally believed, and as most writers had previously assumed to be the case.

In fact these experiments gave us very little encouragement as to the use of water as a destructive agent, and we can readily understand how eggs may hatch out, as they have been known to do, in marshy soil, or soil too wet for the plow; or even from the bottom of ponds that were overflowed during the winter and spring. While a certain proportion of the eggs may be destroyed by alternately soaking and drying the soil at short-repeated intervals, it is next to impossible to do this in practice during the winter season as effectually as it was done in the experiments; and the only case in which water can be profitably used is where the land can be flooded for a few days just at the period when the bulk of the eggs are hatching.

(4) Tramping.—In pastures or in fields where hogs, cattle, or horses can be confined when the ground is not frozen, many if not most of the locust eggs will be destroyed by the rooting and tramping.

(5) Collecting.—The eggs are frequently placed where none of the above means of destroying them can be employed. In such cases they should be collected and destroyed by the inhabitants, and the State should offer some inducement in the way of bounty for such collection and destruction. Every bushel of eggs destroyed is equivalent to a hundred acres of corn saved, and when we consider the amount of destruction caused by the young, and that the ground is often known to be filled with eggs; that, in other words, the earth is sown with the seeds of future destruction, it is surprising that more legislation has not been had looking to their extermination.

One of the most rapid ways of collecting the eggs, especially where they are numerous and in light soils, is to slice off about an inch of the soil by trowel or spade, and then cart the egg-laden earth to some sheltered place where it may be allowed to dry, when it may be sieved so as to separate the eggs and egg-masses from the dirt. The eggs thus collected may easily be destroyed by burying them in deep pits, providing the ground be packed hard on the surface. In the thickly settled portions of Europe, where labor is abundant and cheap, this method may be adopted with some advantage, but it will scarcely be employed in this country, except as a means of earning a bounty, when, in the

more thickly settled sections, it will prove beneficial and give employment to young people and others who have nothing else to do.

DESTRUCTION OF THE YOUNG OR UNFLEDGED LOCUSTS.

In the destruction of the young, no methods that will not sweep them away in wholesale fashion have any value for our western farmers, however valuable they may be to the owner of a small flower or truck garden. It is for this reason that we have been able to profit so little by European methods, and have had to invent means suitable to our broad western fields and the extensive nature of our farming operations. The best that most European authors can advise is the killing of the insects with flattened implements or brush; while Gerstäcker and other writers devote page after page to prove the superiority over other methods of catching the insects with hand-nets—a method which, while doubtless of some utility in dense German settlements, would prove absolutely futile on our large and scattered prairie-farms and against the excessive numbers of the pests which our farmers have to deal with. While, therefore, we shall mention all available means that have been or may be employed, we shall devote more especial attention to those which are useful in a broad and general way in the field.

Experience has shown that the results of any particular measure will vary in different regions, dependent, to some extent, upon the nature of the soil, the condition of the crops, and the general characteristics of indigenous vegetation. Circumstances may also render some particular measure available and profitable to one farmer where it would be unprofitable to another. For convenience, the means of accomplishing the desired result may be classified into: (1) Burning, (2) crushing, (3) trapping, (4) catching, (5) use of destructive agents.

(1) BURNING.—This method is, perhaps, the best in prairie and wheat-growing regions, which compose the larger part of the area subject to devastation by this locust. In such regions there is usually more or less old straw or hay which may be scattered over or around the field in heaps and windrows, and into which the locusts, for some time after they hatch, may be driven and burned. During cold or damp weather they congregate of their own accord under such shelter, when they may be destroyed by burning without the necessity of previous driving. Much has been said for and against the beneficial results of burning the prairies in the spring. This is chiefly beneficial around cultivated fields or along the roadsides, from which the locusts may be driven, or from which they will of themselves pass for the shelter the prairie affords. Scarcely any eggs are laid in rank prairie, and the general impression that locusts are slaughtered by myriads in burning extensive areas is an erroneous one, at least in the temporary region.

In burning extensive prairies after the bulk of the locusts hatch, the nests and eggs of many game birds are destroyed; but as the birds themselves escape destruction on the wing, they may and do return and

nest again, while, on the contrary, many injurious insects, like the chinch-bug, for instance, are killed; so that, even leaving the locust question out of consideration, the burning proves beneficial by exterminating other noxious insects, and has some advantages from an agricultural point of view.

As locusts disperse more and more from their hatching-grounds into the prairie as they develop, burning the grass in spring is beneficial in proportion as it is delayed.

Machines for burning have been used in several localities with considerable success. Mr. J. Hetzel, of Longmont, Colo., has employed a machine drawn by horses. It is 12 feet long, from 2 to 2½ feet wide, made of iron, and set on runners 4 inches high. An open grate on the top of the runners is filled with pitch-pine wood, a metal sheet covering the grate to keep the heat directed downward. The grate is generally made with a net-work of heavy wire, such as telegraph wire. Two men and a team can readily burn from 10 to 12 acres a day and kill two-thirds of the insects, but for this it requires a hot fire.

Mr. C. C. Horner gives a more detailed description in the *Colorado Farmer* of a machine of somewhat similar construction:

> It consists of three runners, made of 2 by 4 scantling, 3 feet in length, to be placed 6 feet apart, making the machine 12 feet wide; runners to be bound together by three flat straps or bars of iron (the base being 12 feet long). Across the top, bars of iron hold the runners firmly together, and form a frame across which wire can be worked to make a grate to hold fire. The upper part of the runners should be hollowed out so that the grate may slide along within 2 inches of the ground. A sheet-iron arch should be set over this grate to drive the heat downward. This machine is very light, and can be worked with one horse. Pitch wood is best adapted to burning, and can be chopped the right length and size and left in piles where most convenient when needed. This machine is intended to be used when the little 'hoppers just make their appearance along the edge of the grain, going over the ground once or twice each day, or as often as necessary to keep them killed off. The scorching does not kill the grain, but makes it a few days later. This is cerainly the cheapest as well as the most effectual manner of getting rid of this pest.

Hand burners, consisting of any form of pan or grate, or wire sieves, with handle attached, to hold combustible material, will do excellent service in gardens and small inclosures.

There is another method by which large numbers of locusts can be burned, consisting merely of a bundle of rags or tow, which, after being attached to long wire or iron rods and saturated with kerosene, can be ignited and carried over the field. This method has been quite satisfactorily used in Colorado. A stout wire, say 40 feet long, is thoroughly enveloped in rags soaked in coal oil. A small wire is wound around the rags to keep them in place, and the simple device is complete. Two men carry this rope, after setting fire to the rags, across the field to and fro until the fuel is exhausted, and as it is not necessary to pass over the same ground more than once or twice, a large field of grain can be thus protected during the half hour or so that the rags burn. The effect is that of a miniature prairie fire.

Under this head may be mentioned a machine constructed by Mr. Kimball C. Attwood, of Syracuse, New York (patent No. 193,105, dated July 17, 1877), for destroying the insects by sulphur fumes. The machine is too expensive and complicated to come into general use, especially as it is less effectual than some of the simpler ones. The principle of the invention consists in attaching to the axle of the machine a light stove and connecting the same with a blower or bellows by means of a tube. Surmounting this tube, and close to the stove, is situated the hopper for the reception of the destroying compound (sulphur), while the lower section of the stove is connected with an escape-pipe having attached thereto a series of flexible tubes, by means of which the fumes of the compound are carried to the ground. Attached by suitable means to the rear of the axle is a horizontal bar, to which is secured the apron or cover designed to prevent the escape of the fumes after being delivered by the flexible tubes.

Other machines have been constructed, having troughs or wire receptacles attached, in which the locusts are deposited and ultimately destroyed by means of sulphur fumes or hot water. But as these remedies are applied by hand, they will be classed under the head of *Catching*, etc.

(2) CRUSHING.—The satisfactory destruction of locusts by this means can only be advantageously accomplished where the ground is smooth and hard. Where the surface of the ground presents this character, heavy rolling can be successfully employed, especially in the mornings and evenings of the first 8 or 10 days after the newly hatched young have made their appearance, as they are generally sluggish during those times, and huddle together until after sunrise. It is also advantageously employed during cold weather at any time of day, since the young when the temperature is low seek shelter under clods, etc. In various parts of Europe and Asia flat, wooden, spade-like implements are extensively used for crushing young locusts. Large brushes, weighted down with stone and drawn by horses, were in some instances used last summer, but with less success than was anticipated.

Several machines, most of them patented, were for the first time used during the past year to further the crushing of the young, and while none of them are likely to take the place of the more simple methods of catching, to be presently described, we nevertheless feel that it devolves upon us to describe some of them. That represented on Pl. I was invented by Mr. George B. Drum, of Syracuse, Nebraska (patent No. 187,258, dated February 13, 1877). Fig. 7 is a vertical section on line *x*. Fig. 6 is a plan view with a part of the top removed, showing the mechanism.

Another is that invented by Mr. Michael H. Simpson, of Boston, Massachusetts (patent No. 198,420, dated December 18, 1877). Pl. II, Fig. 1, represents a perspective view of the machine; Pl. II, Fig. 2, a sectional view of the same as shown in the preceding; and Pl. II, Fig. 3, a sectional view of the same arranged for the removal of the insects.

Another machine that may be mentioned in this connection is that invented by Mr. Charles Hoos, of Arago, Nebraska (patent No. 187,155, dated February 27, 1877). In the accompanying illustrations, Pl. II, Fig. 4, represents a top view of the machine; Pl. II, Fig. 5, is a vertical section of the same taken through the line *x x;* and Pl. III, Fig. 1, is a side view.

I witnessed the working of a machine invented by Mr. T. K. Hansberry, of Padonia, Kansas (patent No. 188,359, dated March 13, 1877), intended to crush the insects by means of movable wooden bars. It does not prove very successful, however, except on the very smoothest ground. Pl. III, Fig. 2, is a top view, when mounted on wheels or runners; Pl. III, Fig. 4, represents the front. Pl. III, Fig. 3, is a sectional view of the machine when on runners, with knives or bars attached; and Pl. III, Fig. 5, shows the slide attached, close to the axle, to close the angle formed at the side by the ground and the knives or bars when the machine is mounted on wheels.

Mr. Elisha Kenworthy, of Walnut, Iowa, has invented a machine (patent No. 186,970, dated December 5, 1876) which can be placed under this class of machines. Pl. III, Fig. 7, presents a vertical section of the invention, and Pl. III, Fig. 6, a plan view of the same.

Numerous communications upon this subject have been received, some of which, if not all, are or may have been successful on a small scale. Others, if carried out, and the contrivances built and given a fair trial, might be of especial benefit.

Mr. J. C. Melcher, of O'Quinn, Tex., constructed one which he describes as follows:

> It is constructed on the hand lawn-mower style, mounted on light wheels, a disturbing rim, 8 or 10 feet long, passing low over the ground to stir the 'hoppers up. Just behind the disturber are two sheet-metal rollers, one of which drives an endless band. As soon as the 'hoppers jump over the disturber, the band catches them and crushes them between the rollers. The rollers, being of sheet-iron, are elastic enough to press uniformly at any given point. A rack of wire web or cloth ascends over the top of the machine to prevent the 'hoppers from escaping. It is operated by two men pushing the machine before them.

Mr. John Wise, of Nebo, Platte County, Nebraska, says (in a letter dated May 26, 1877) "a good machine can readily be made by having two revolving rollers mounted on wheels, the rollers to be 4 or 6 inches above ground, so arranged, if need be, to be adjusted either higher or lower, the upper to revolve on the top of the lower," etc. To a contrivance of this sort handles could be attached for pushing, and, with the addition of a frame covered with cloth or muslin, projecting forward and outward.

In addition to the preceding contrivances for crushing locusts is one invented by Mr. F. Peteler, of Minneapolis, Minnesota.

Pl. IV represents a front view, and Pl. V, Fig. 1, a side view, of the same machine.

In a communication from the inventor, dated June 8, 1877, the follow-

ing description is given: The machine is intended to be drawn by horses, the drawing representing one to be drawn by a team. "The frame is mounted upon two wheels. The front is a sheet-iron platform, over which revolves an elevator made of slats, which carry the locusts into boxes, where they pass between rollers, are crushed, and fall to the ground. The sides and top or back are wire screws, the whole forming a scoop 16 feet long (on the bottom 19 feet), 8 feet high, the top of which can be lowered or raised according to the height of the grain or grass."

A more detailed description follows:

AA, driving-wheels; B, guiding-wheel; D, setting-lever; *d*, retaining-post; G, endless carrier; H*h*, gearing for elevator and crushing-shaft; I, crushing-rollers; L, set-screw to spiral spring; *l*, spiral spring to press rollers together when necessary; N, slats on endless chain with sheet-iron projections to hold the locusts; M, drag-chain (or strips of light wood) to stir the locusts.

Mr. Peteler believes that, with a single-horse machine, 40 or 50 acres can be gone over in a single day, and by changing horses more can be done; but we, unfortunately, had no opportunity to test the practical working of the machine, as, by the time it was perfected, simpler and satisfactory methods were extensively being employed in Minnesota, and the inventor did not feel encouraged to manufacture his machine. Indeed, its expense is too great to warrant its manufacture, except to order by clubs of farmers. To use Mr. Peteler's own words: "This machine is intended for local or State authorities to use on uncultivated lands adjoining farms and unsettled prairies, in order to destroy the insects during the entire season; for that purpose there should be proper organization, with camp outfit, etc., to follow up the swarms, loading the machines on wagons, and battle with the 'hoppers morning and evening, when they are comparatively sluggish. These machines are not designed as temporary contrivances, believing that we shall have the scourge several seasons in some parts of the State, and they should be made strong and durable." Instead of paying bounties from the State treasury for the locusts, Mr. Peteler would have the State aid the farmers by investing in these machines. "Fifty thousand dollars advanced to farmers will place, at $40 each, 1,250 one-horse machines in their hands to keep their grain-fields clear. If they use them only 60 days during the season, and go over only 40 acres per day, destroying but one-half bushel per acre (frequently they would destroy 8 to 10 bushels per acre), they would send 25,000 bushels daily, or 1,500,000 in 60 days, where bad 'hoppers go. That money would be returned to the State in 4 to 6 months by the farmers, provided the State and local authorities will do their duty by destroying the pests on uncultivated lands."

Under this head we may mention the curious suction-fanning machine invented by Mr. J. A. King, of Boulder, Colorado, and one of which, purchased by Mr. T. C. Henry, of Abilene, Kansas, we had the

opportunity to fully test. It consists of two large tin tubes (Pl. v, Fig. 2, AA), about 8 inches in diameter, with flattened, expanded, and lipped mouthpieces, B, running near the ground. This horizontal opening or mouth is about 7 feet long. The tubes connect at the upper extremity with a chamber, C, in which is a revolving fan which makes about 1,200 revolutions per minute. The tubes and fan, with the gearing, are placed in a frame, D, 5 by 10 feet, mounted upon two large driving wheels. EE Pl. vi represents this machine in operation.

The air current made by the revolving fan creates a suction at the mouth, which draws the insects up the tubes and into the chamber. They are then thrown by the fan upon a wire screen, and from thence drop into a kind of hopper which conducts them to a bag. The wire screen rapidly chokes up and must be frequently cleaned. Most of the locusts are crushed and mangled by the rapidly revolving fan, so that the screen may be removed entirely and the locusts thrown out behind. This allows a freer draft and causes a greater suction. This machine can be made for about $50, and it works well on smooth ground or in a wheat field while the wheat is yet short. It is somewhat difficult to keep the lips close enough to the ground. The principle of the machine is a good one, and we see no reason why some cheaper modification of it should not be quite generally used early in the season, especially in Colorado, where there is so much hard, smooth ground around the cultivated fields. The lips might be protected and rendered less liable to bend and get out of order by moving on runners made to extend some distance in front.

Finally, a machine which we saw in Colorado, and which was put up by J. S. Flory, of Greeley, Colorado, is worthy of mention in this connection; for, while it may be used with coal-tar, it is essentially a catching and crushing machine. The Colorado Sun thus speaks of it:

> The main feature of this invention is a revolving platform of heavy canvas or wire cloth, which runs between two horizontal rollers. Long arms reach forward, which support a revolving reel; from these arms downward extend sheet-iron sides, over the top a canvas covering; all so constructed as to form a large wide mouth, into which the 'hoppers are driven by the arms of the revolving reel and carried between the two rollers and crushed. Horizontal strips running along the rollers serve to keep the rollers and platform clear of the crushed grasshoppers. The whole machine is supported on two main wheels about the middle and two smaller ones in front. Extending back is a frame or cross-bar, to which one or two horses may be hitched to push the machine forward, or it may be operated by hand. The front of the platform runs close to the ground, and by bearing down at the rear by the driver it can easily be lifted over any obstruction that may be in the way. The machine can be raised or lowered in front to suit the crop over which it is run.
>
> This invention will destroy the grasshoppers without the necessity and expense of using oil or tar. The patent, we understand, also covers the combinations of a receptacle immediately under the rollers, into which the grasshoppers are carried, and in which, if need be, water and oil may be kept, and also a long narrow hopper (just over the rollers), into which coal-tar may be put and allowed to run through onto the platform, thus making it a *self-tarring machine*. Either of these combined methods of destroying the 'hoppers may be used as the farmer may choose. The

machine is so simple in construction that any ordinary workman can put them up at a comparatively small price. The machine may be made of any size desired, from a small hand-machine to one a rod or more in width.

Pl. IX, Fig. 2, represents a front view of this machine when in operation, and Fig. 3 a side view of the frame.

(3) TRAPPING.—This can be easily accomplished, especially when the locusts are making their way from roads and hedges. The use of nets or seines, or long strips of muslin, calico, or similar materials, converging after the manner of quail nets, has proved very satisfactory. By digging pits or holes 3 or 4 feet deep, and then staking the two wings so that they converge toward them, large numbers may be secured in this way after the dew is off the ground, or they may be headed off when marching in a given direction. Much good can be accomplished by changing the position of the trap while the locusts are yet small and congregate in isolated or particular patches.

Ditching and *trenching* properly come under this head; and both plans are very effectual in protecting crops against the inroads of traveling schools of the insects. They were found especially advantageous in much of the ravaged country in 1875, where there was little or no hay or straw to burn. They are the best available means when the crops are advanced, and when most of the other destructive methods so advisable early in the season can no longer be effectually used. Simple ditches, 2 feet wide and 2 feet deep, with perpendicular sides, offer effectual barriers to the young insects. They must, however, be kept in order, so that the sides next the fields to be protected are not allowed to wash out or become too hard. They may be kept friable by a brush or rake.

The young locusts tumble into such a ditch and accumulate and die at the bottom in large quantities. In a few days the stench becomes great, and necessitates the covering up of the mass. In order to keep the main ditch open, therefore, it is best to dig pits or deeper side ditches at short intervals, in which the locusts will accumulate and may be buried. If a trench is made around a field about hatching-time, but few locusts will get into that field until they acquire wings, and by that time the principal danger is over, and the insects are fast disappearing. If any should hatch within the inclosure, they are easily driven into the ditches dug in different parts of the field. The direction of the apprehended approach of the insects being known from their hatching locality, ditching one or two sides next to such locality is generally sufficient, and when farmers join they can construct a long ditch which will protect many farms.

Where the soil is tenacious and water can be let into the ditches so as to cover the bottom, they may be made shallower and still be effectual. The width and depth of the ditch is important, and as experience differed somewhat, I have been at pains to get the experience of a large number of correspondents addressed by circular. Many have success-

fully used ditches 2 feet deep and 18 inches wide; a few have made them only 18 inches by 18 inches. Those who have used water found 12 inches by 15 inches sufficient, while the larger number used a ditch such as I have recommended, viz, 2 feet deep by 2 feet wide, with perpendicular sides. Having been the first to recommend proper ditching in this country, I have felt particular interest in its results, and have been in no small degree amused at the fault found with my recommendation by those who, through slovenly made ditches or other causes, have not been successful in this mode of warfare. It is less effectual against the newly-hatched young, which more easily crawl up a perpendicular bank than the larger ones, and its efficacy will vary with the nature of the soil and other circumstances; for, in proportion as the soil is loose, and the ditches hence apt to fill up by the action of strong winds, or in proportion as strong winds carry the insects over, ditching will necessarily fail.

Those who, from theory rather than from experience, are skeptical about the efficacy of ditching, urge that the locust, especially in the pupa state, can hop more than 2 feet. In truth, however, whether when traveling in a given direction of their own accord, or when being driven or disturbed, they very seldom leap that distance, as all who have had experience well know. That, on a pinch, the pupa can leap even farther, is true; but the fact remains that in practice *Caloptenus spretus* seldom does. So the Chinch Bug, though capable of flight, will yet tumble into a ditch by myriads rather than use its wings. Even the larger winged Acridia and Œdipodæ tumble into such a ditch, and seldom get out again. I would remark in this connection, also, that a ditch 3 feet wide, unless correspondingly deep, will be more apt to permit the insects to escape, when once in, than a narrower one. In hopping, the more perpendicular the direction the insects must take, the shorter will be the distance reached.

The efficacy of the ditch depends not so much on the inability of the young locusts to jump or scale it, as on their tendency not to do so. In the bottom of the ditch they soon become demoralized, crippled, and enfeebled by constant effort and the trampling and crowding upon one another.

Protection by Barriers.—Where ditches are not easily made, and where lumber is plentiful, a board fence 2 feet high and with 3-inch batten nailed to top on side from which the locusts are coming, the edge of it smeared with coal tar, will answer as an effectual barrier and prove useful to protect fields or gardens.

A modification of this method was used with great success in 1883 and subsequent years in the Isle of Cyprus. The "Cypriote system," as it has been called, consists of a series of traps and screens. The screens are made of light hemp canvas, 50 yards long and 2 feet 6 inches wide. Near the upper edge of the canvas is sewn a strip of oil-cloth 4 inches wide. The screens are fixed to stakes of hard wood firmly

driven into the ground at intervals of 13 feet 6 inches, slightly inclined towards the direction from which the attack of locusts is expected. A cord is stretched from stake to stake. The screens are tied to the inside (locust side) of the stakes and to the cords by tapes. About 6 inches in width of the lower edge of the canvas is folded on the ground inside the stakes and weighted with earth. Pits are dug at intervals of generally from 40 to 50 yards, and the usual size of the pits is 6 feet long, 2 feet 3 inches wide, and 3 feet deep. Round the edges of the pit is fixed the trap, consisting of four strips of zinc 9 inches wide. The screens having been so fixed as to head the advancing army of locusts, they march until their progress is stopped by the screen. They climb up the canvas until they reach the oilcloth, which they can not pass. They then descend and crawl to one side or the other until they fall into the pits, from which they attempt to escape by climbing up the sides until they encounter the zinc sheets which project 4 inches from the edge. They then fall back into the pit and when this is full to within about 9 inches of the brim earth is shoveled in to bury the locusts, a new pit having been excavated in the meanwhile to one side. The trap is removed to the new pit, and the same thing is repeated until the whole swarm has been destroyed. The use of this system has practically rid Cyprus of the locust plague, and has also been of great avail in Algeria after other methods had failed.

Coal Oil.—The use of coal oil and coal tar may best be considered in this connection, as both substances are employed in various ways for trapping and destroying the insects. As we shall presently see, in considering the different available destructive agents, coal oil is the very best and cheapest that can be used against the locusts. It may be used in any of its cruder forms, and various contrivances have been employed to facilitate its practical application. The main idea embodied in these contrivances is that of a shallow receptacle of any convenient size (varying from about 3 feet square to about 8 or 10 by 2 or 3 feet), provided with high back and sides, either mounted upon wheels or runners, or carried (by means of suitable handles or supporting rods) by hand. If the "pan" is larger than, say, 3 feet square, it is provided with transverse partitions which serve to prevent any slopping of the contents (in case water and oil are used), when the device is subjected to any sudden irregular motion, such as tipping, or in case of a wheeled pan, when it passes over uneven ground. The wheeled pan is pushed like a wheelbarrow; the hand-worked pan is carried by long handles at its ends. On pushing or carrying, as the case may be, these pans, supplied with oil, over the infested fields, and manipulating the shafts or handles so as to elevate or depress the front edge of the pan as may be desired, the locusts are startled from their places and spring into the tar or oil, when they are either entangled by the tar and die slowly, or, coming in contact with the more active portion of the oil, expire almost immediately. In Colorado they use it to good advantage on the water in their irrigating

ditches, and it may be used anywhere in pans or in saturated cloths, stretched on frames, drawn over the field. The method of using it on the irrigating ditches in Colorado is thus reported by Prof. R. L. Packard:

It consists essentially in pouring, or, better, dropping coal tar or coal oil on the running water with which the irrigating ditches are supplied. The method of supplying these ditches with oil is very simple. It is only necessary to sprinkle a few drops of coal tar on the stream, when the oils contained in the tar are diffused over the surface of the water, and coming in contact with the insects (no matter how many), cause their speedy death. The toxic power of coal oil upon the insects is very remarkable; a single drop of it floating on the water is capable of causing the death of a large number of insects. A simple and ingenious mode of keeping up a constant supply of the tar to a ditch I saw exemplified upon the farm of Mr. Arnett. A three-quart can is perforated on the side close to the bottom, a chip loosely fitting the aperture is inserted therein, and the can is then immersed (by a weight if necessary) in the ditch. Three quarts or less of tar, trickling out drop by drop from this slight vent, are sufficient to keep a great length of ditch supplied with coal oil for 36 hours. The precise extent of ditch which may thus be rendered toxic to the locusts can not, of course, be exactly stated. It is in fact quite indefinite, for the reason that the quantity of oil necessary to kill one of the insects is almost infinitesimal, and for the further reason that a single drop of oil will cover quite a large surface when dropped on water, so that taking these two facts together, it is easy to see that a very small quantity of tar or oil will serve to guard by means of ditches a large tract of territory from the ravages of the young (unwinged) locusts.

The pans that were used in Kansas and Iowa, but principally in the former State, were of very simple construction and very effectual.

A good and cheap pan is made of ordinary sheet-iron, 8 feet long, 11 inches wide at the bottom, and turned up a foot high at the back and an inch high at the front. A runner at each end, extending some distance behind, and a cord attached to each front corner, complete the pan, at a cost of about $1.50. (Pl. VIII, Fig. 2.)

We have known from 7 to 10 bushels of young locusts caught with one such pan in an afternoon. It is easily pulled by two boys, and by running several together in a row, one boy to each outer rope, and one to each contiguous pair, the best work is performed with the least labor. Longer pans, to be drawn by horses, should have transverse partitions (Pl. III, Fig. 8) to avoid spilling the liquid; also more runners. The oil may be used alone so as just to cover the bottom, or on the surface of water, and the insects strained through a wire ladle. When the insects are very small, one may economize in kerosene by lining the pan with saturated cloth, but this becomes less efficient afterward, and frames of cloth saturated with oil do not equal the pans. Where oil has been scarce, some persons have substituted concentrated lye, but when used strong enough to kill it costs about as much as the oil. The oil pans can be used only when the crops to be protected are small.

Small pans for oil, attached to an obliquing pole or handle, do excellent service in gardens.

Mr. A. A. Price, of Rutland, Humboldt County, Iowa, sends the commission the following description of a coal-oil pan to be drawn on runners, and which was used with much success in northwestern Iowa (Pl. VIII, Fig. 1):

Take a common board from 12 to 16 feet in length for the foundation or bed piece. Make a tin trough 4 inches deep, 6 inches wide, and as long as required. Divide the trough into partitions by means of strips of tin, so that each partition is a foot long, thus avoiding the spilling of oil. Back of this place a strip of tin 16 inches wide and as long as the trough. The back must be firmly secured by braces running down to the front edge of the board. Under all this place 3 wooden runners 3 feet long and shod with iron for the trough to ride on. Fill the pan half full of water, and then add a small quantity of kerosene—sufficient to cover the water. A horse may be hitched to the machine by fastening a rope to the outside runners. * * * The lightness of the machine will allow of its being used on any crops. * * *

A machine of this sort was patented by Mr. Lorenzo B. Canfield, of Syracuse, Nebr. (Patent No. 187,509, dated February 20, 1877). The following description and figures will serve to illustrate his pan more fully. Pl. VII, Fig. 1, represents a perspective view; Pl. VII, Fig. 2, a longitudinal sectional view on the line *x x* in the preceding.

This pan was sold in the West at an exorbitant price, $4 being charged for royalty. Wherever we had an opportunity we advised farmers not to use it, but to construct others such as we have already described, and every bit as good, at far less expense. The principle can not be patented, for since 1875 similar coal-oil pans, virtual outgrowths of the canvas frames originally employed for the same purpose, have been "known and used" in Colorado. This fact is sufficient in law to defeat any patent right based upon any application for a patent subsequent to such knowledge and use.

The essential features in all the contrivances are, in fact (1) A platform that runs on the ground, on runners or wheels; (2) A canopy at right angles with it; (3) A reservoir at the junction to contain the liquid.

Another pan, of which we give a sketch (Pl. VII, Fig. 3), was made by Mr. James Adams, of Abilene, Kansas. It is 10 feet long, 2 feet wide; back (*a*) 1 foot high; front (*b*) about 2 inches high at the inner edge; ends (*c*) 2 feet high. The front is made of a board 6 inches wide, leaning inward at an angle of about 45°. A cloth screen is placed on the back part, which prevents the reel from knocking the locusts back over the pan.

The whole is made of pine, and it costs $8 or $10. The pan is painted within with asphaltum paint, which renders it impervious to water or oil. The pan rests in front upon runners, to which ropes are attached for drawing, and on wheels behind which carry belts to turn the reel.

The reel revolves just in front of the pan, causing the locusts to hop, and then knocking them into the pan. A brush of cloth is sometimes fastened to one arm of the reel to brush into the pan any locusts that may be on the front piece. Several of these pans were used about Abilene, and did good work.

A contrivance shown in Pl. VIII, Fig. 3, was constructed by President John A. Anderson for use on the Agricultural College farm at Manhattan, Kansas.

It was found to do very good service, killing the young locusts in considerable numbers. The oil did not evaporate so rapidly as was anticipated. One thorough saturation was sufficient for fifteen or twenty minutes, when a little more could be added. If the machine be hauled against the wind, nearly all the locusts which hop will touch the oiled canvas. They generally take several hops upon the canvas before leaving it, thus insuring a thorough saturation with the oil. After hopping from the apron they can take two or three hops upon the ground, then lose all power in their hind legs, stretching them straight out behind, and finally, in one or two minutes after being "oiled," they are dead.

Coal Tar.—This may be used with most of the contrivances just described for the use of kerosene, and while not equal to the simple kerosene pan for speed in trapping and destroying, is yet very useful, especially in the neighborhood of gasworks where the coal tar can be obtained at nominal cost. It also permits the use of the simplest kind of pan. Enough tar is spread over whatever receptacle may be used to cover well the bottom, and when this becomes sufficiently matted with the young locusts so as no longer to destroy the new comers, another coating is added, and so on until it becomes necessary to remove the whole mass, when it is shoveled from the pan and burned; or, what is far preferable, wherever there are wet ditches it may be thrown into these, when the oil contained in it, spreading over the surface of the water, destroys such locusts as may jump into or be driven into such ditches. Where the tar is scarce, as a matter of economy it will pay to melt the accumulated mass in iron vessels. By skimming off the dead locusts that rise to the surface, and thinning the residuum with a little coal oil, it may be used again.

A simple pan extensively employed, and which was known as the Robbins "hopperdozer,"* is shown in the accompanying illustration (Pl. IX, Fig. 1), the general plan being that of the ordinary road scraper. Its simplicity and durability account for its general use. It was usually drawn by hand, though several pans were frequently bound together and drawn by horses; while, in some instances, certain improvements in the way of mounting on wheels, so as to permit its being pushed from behind, were also adopted. We saw some with a wire screen or cover hinged to the back, so that the insects might be secured when the pan was not in motion; but the cover seemed superfluous. We also saw lime and kerosene mixed so as to form a mortar substituted for the coal tar.

Another device was used in Colorado last summer, but is more complicated. It consisted of a skeleton cylinder of wood framework covered with canvas, the interior of which was to be coated with coal tar. The ends were opened and fans were arranged there, so constructed as

*A word that came into very general use last year among farmers for coal-oil and coal-tar machines, and which doubtless takes its origin from doze, in reference to the toxic effect of the coal-tar on the locusts.

to throw the locust into the interior of the cylinder, where they would become entangled in the tar and be poisoned by it. The machine runs on wheels whose axle is the axis of the cylinder.

A correspondent of *The Kansas Farmer*, in the issue of June 6, 1877, describes the following contrivance:

I yesterday put together a machine which I do not propose to patent. It is constructed as follows: I had riveted together two sheets of stove-pipe iron, each 2 by 7 feet, making a surface of 4 by 7 feet. I rolled up the back side about 18 inches high, and held it to its place by nailing to it rounded inch boards. I turned up the front a trifle, and nailed to it a narrow strip of siding to stiffen the machine under the bottom, well back, so that it would balance. I fixed a three-eighths round iron for an axle, and fastened it by driving a staple over it near the ends and into the board end pieces. The wheels should be 16 inches in diameter, made of inchboards, three thicknesses nailed together, so that the grain of the wood will cross. I push my machine with a handle made of half-inch iron, a piece 12 feet long, the ends flattened, and fastened to the end board with screws, the rod bent up and made the proper shape, so as to come about to the bottom of a man's vest when operating the "dozer." I cover the surface with tar (common), which will burn and is poison to the 'hopper. The machine tilts over the axle and can be made to scrape the ground or raised to pass over grain or obstructions. The "dozer" is a perfect success, gathers the 'hoppers almost as clean as a reaper will cut grain; none get away. One week's work and 4 gallons of pitch tar will clean the worst 'hoppered 160-acre farm in Minnesota. At one priming with tar yesterday my man caught in about an hour a half bushel, estimated to make 10 bushels when grown.

(4) Catching or Bagging.—"There are innumerable mechanical contrivances for this purpose. The cheapest and most satisfactory are those intended to bag the insects. A frame 2 feet high and of varying length, according as it is to be drawn by men or horses, with a bag of sheeting tapering behind and ending in a small bag or tube, say 1 foot in diameter and 2 or 3 feet long, with a fine wire door at the end to admit the light and permit the dumping of the insects, will do admirable work. The insects gravitate toward the wire screen, and when the secondary bag is full they may be emptied into a pit dug for the purpose. Those bagging-machines will prove most serviceable when grain is too high for the kerosene pans, just described, and they will be rendered more effectual by having runners at distances of about every 2 feet, extending a foot or so in front of the mouth, so as to more thoroughly disturb the insects and prevent them from getting underneath; also by having wings of vertical teeth, so as to increase the scope with as little resistance to the wind as possible."

Two important facts should always be borne in mind in using these bagging-machines: First, that they should always be drawn, as far as possible, against the wind, if this be stirring; second, that in proportion as the insects and the grain are advanced in growth, and the former become predisposed to roost, in that proportion the machines will prove more serviceable at night.

We constructed a machine embodying the features already mentioned, and it answered the purpose very well indeed. The following account is from the *Scientific American:*

Professor Riley, of the Entomological Commission, perfected last summer a grasshopper machine, which seems to be just the thing. It is intended to do away with all extra material, like coal-oil, which in the long run is expensive, and to work at all seasons, whether the insects are just hatching or full grown. It is not patented, nor does the professor intend to patent it, unless it should be found necessary to prevent others from doing so. It was worked at Manhattan, Kansas, and gave great satisfaction, and was described in the *Industrialist*, the organ of the Kansas State Agricultural College, as follows: (See Pl. X, Fig. 1.)

"The mechanical department has constructed a new locust exterminator for Professor Riley. The machine operates upon the bagging principle. It is, briefly, a large canvas bag stretched upon a light but strong frame, and placed upon runners, which extend with curved tips a little in front of the mouth. The canvas is stretched upon the inside of the frame, thus making the bag smooth and even within. This bag has a mouth (A) 10 feet long and 2 feet high, and converges backward to a small box or frame, 1 foot square, with a slide cut-off (D). This box forms the mouth to a secondary bag (B), 2½ feet long and 1 foot in diameter, which ends in a second frame having two short runners below it. There is a sliding door (E) of wire gauze in the end frame, and the secondary bag is strengthened by a couple of strips of leather connecting the two small frames. The machine is made to "take more land" by means of two right-angled triangular wings (C) about 6 feet long, that hinge to the upright ends of the large frame in such manner that the rectangle joins the upper corner of the frame. From the lower side of this wing are suspended a number of teeth, or beaters, which, swinging loosely, drive the locusts inward. The machine is handled by means of two ropes hitched to the outer runners or to the outer and lower side of the mouth of the frame.

"On smooth ground the machine can be easily hauled by two men, but where the grass is tall and thick it pulls harder. The locusts, on hopping into the machine, soon reach the small back portion, enter the small bag, and are attracted to the rear end by the light which enters by the gauze door. When a sufficient number are thus captured the machine is stopped, the cut-off is slid down in front of the secondary bag, a hole is dug behind the machine, the bag tipped into it, and the insects buried. A strip of leather closes the slit through which the cut-off slips, and the main bag is made of dark cloth, while the secondary bag is white, so as by contrast to attract more thoroughly the locusts.

"The advantages of this machine are that it requires no additional expense to run it, as for oil, tar, etc. It will catch the winged locust as well as the young, if operated on cool mornings and evenings, and is adapted to almost all conditions of growing grain. The machine can be made for about $10, and perhaps less."

In practice we found it best to draw the machine by hitching to the runners, and to brace the wings at desired angles, according to the strength of the wind, by means of two iron rods, as in the illustration.

A net which has done good service, made by Maj. J. G. Thompson, of Garden City, Minnesota, is as follows:

Two pieces of common batten about 16 feet long were used as framework for the mouth of the net, one for the bottom and one for the top. From the end of the bottom piece a wooden shoe of the same material ran back about 6 feet to steady the trap, and serve as a runner. To the rear end of this shoe a similar piece was fastened by a hinge, and ran forward and was fastened to the top piece of the frame, so that the mouth of the trap would open and shut like a jaw. To hold the mouth open, two short, upright posts were fastened to the top piece by a hinge, and rested upright upon the bed-piece. The net itself was made of cotton cloth for the bottom, and the top was made of mosquito-netting. The mouth of the net extended 16 feet from one side of the trap to the other, and the net ran back about 6 feet to a point with a hole

at the end to let out the insects collected. A boy 10 years old can draw one end of this net, and by the use of it, Major Thompson saved one piece of wheat.

Mr. J. C. Elliot, of Sheldon, Iowa, thus describes a machine of his own devising that was much liked in his section:

Take a strip of pine lumber 1 inch thick, 2 inches wide, and 10 or 12 feet long; about 18 inches from each end mortise in a strip about 2 feet long of the same material as your main piece; run a strong wire from one end of the main piece over the ends of the two upright pieces and fasten to the opposite ends of the main strip, forming the framework to the mouth of your dozer. The wire should be permanently fastened to the top ends of the upright pieces to form a brace to keep them always in place. Place the long strip of lumber on the ground so that the standards stand perpendicular; take two widths of strong cotton cloth the length of your main strip sew them together so you will have double width, tack one side of the cloth to the long wood strip; this forms the bottom. Take of mosquito-bar enough to form a top to the net, fastening one side to the wire running over the top of the standards; put in such gores of cotton cloth at the ends as you may need to form a complete sack of the cotton cloth and mosquito-bar. A good plan to facilitate taking out the 'hoppers when caught is to let the back part of the net run to a point in the center, and leave a small opening, which can be fastened with a string while at work, and unloosened to empty out the 'hoppers. The object of the mosquito-bar is to allow the wind to pass through and keep the 'hoppers in the net.

A very successful method of catching pupæ was used by Mr. Lowe and Mr. Hall, farmers, in McLeod County, Minnesota. It is simply equivalent to a wagon-body with one side removed, to be drawn over the grain after dark. The locusts roosting on the grain fall into it, simply lie there and become entangled in a mass, and may be easily shoveled into a hole. Mr. Hall thinks he caught 800 bushels in the latter part of June; Mr. Lowe, 400.

While in Iowa we inspected one of the following machines, which was not in working order, however, at the time, nor was it much used, even in the locality where invented. It is patented by Mr. George S. Wilson, of Malvern, and Mr. John Rhode, of Tabor, Iowa (patent No. 192,553, dated June 26, 1877), and is described below. (Pl. XI, Fig. 1.)

a a represents two driving-wheels, upon which the machine is propelled about by a person or persons pushing from behind on the handle *c*. The frame consists, preferably, at each end of the two curved timbers *d*, as shown, between which is clamped a curved sheet-metal plate, *e*, which forms the floor of the machine. Secured to the inside edge of the top timber, at each end, is a curved plate, *g*, which forms a flange along each end of the machine, in order to prevent the insects from being swept or jumping from the floor.

To the rear edge of the floor is secured a box or receptacle, *i*, as long as the floor is wide, into which the insects are swept whole by the reel *h*. The cover of this box does not quite reach to the forward edge, thus leaving the space 1, through which the insects fall into the box. The upper end of the lid is turned backward a considerable distance, so as to form the flange 2, thereby preventing the insects from being swept back past the floor and opening 1 upon the ground behind.

Extending across the front edge of the machine is a board or bar, *n*, sharp at its front edge, and the ends of which project beyond each side of the frame, and serve as a support for one of the three braces or standards 3, upon the tops of which the reel is journaled, and operated by the belt or chain 8 over the pulleys 9. The axles 5, upon which the wheels *a* are placed, have their inner ends made U-shaped, so as to

straddle over the edges of the timbers *d*, to which they are secured by set-screws. By thus forming these spindles a heavy axle is dispensed with, and the wheels can be adjusted back and forth, so as to regulate the distance the edge of the floor shall travel from the ground.

The sweeps of the reel may consist either of plain strips of wood, or the strips may have sheets of rubber or any other suitable material clamped in between or secured to them, as shown.

Mr. Samuel Godard, of Marysville, Missouri, invented a machine for catching locusts (patent No. 191421, dated May 29, 1877), of which we give the accompanying illustrations.

Pl. XI, Fig. 3, is a plan view of the invention; Pl. XI, Fig. 4, is a vertical section of the same, and Pl. XI, Fig. 5, represents an end view of the revolving frame.

A machine somewhat like the above was invented by Mr. Finley E. Benson, of Walnut, Iowa (patent No. 184223, dated November 14, 1876). Pl. XI, Fig. 6, represents a plan view of the machine, and Pl. XI, Fig. 7, a vertical section of the same.

The machine invented by Mr. Dexter H. Hutchins, of Algona, Iowa (patent No. 187012, dated February 6, 1877), differs from all the others in having attached a contrivance for killing the insects by means of sulphur fumes. Pl. XII, Fig. 1, is a top view, and Pl. XII, Fig. 2, shows a sectional view.

Another contrivance was invented by Mr. Benjamin Sylvester, of St. Peter, Minnesota (patent No. 188760, dated March 27, 1877), of which drawings are herewith given.

The "Hero 'Hopper-catcher," constructed by John Carlen, Bernadotte, Nicollet County, Minnesota, is a simple bag with fan attachment, working somewhat on the same principle as the above.

Most of these patent contrivances are open to the objection of extra cost and complication without extra efficiency, and the simpler devices will always retain their deservedly greater popularity.

Mr. J. S. Belt, of the firm of Perkins & Belt, St. Paul, Minnesota, constructed a simple sheet-iron pan, intended to hold the locusts without the aid of coal-tar. The machine consists of a sheet-iron platform with a front sweep of 8 feet, the back of which is elevated 7 inches and the front $1\frac{3}{4}$ inches, in the shape of a runner. Over the platform is a contrivance that holds the locusts that hop upon the machine, and an effective cover prevents any from hopping over the grate. The implement is easily pulled by ropes, and, with a 3-foot wing on each side, it sweeps over 14 feet of field. Its capacity is 3 bushels, and it can be emptied in 10 seconds.

The following letter from Mr. Pennock Pusey, private secretary to Governor Pillsbury, expresses the opinion of those fully competent to judge of its value:

This will be handed you by Mr. J. E. Belt, who will exhibit a locust-machine, which strikes the governor and myself as the best thing yet invented. It is on the same simple principle as that of the sheet-iron and tar dozer, but dispenses wholly with

the tar, and thus saves cost and delay. It was tested yesterday by Mr. Raney, of Le Sueur County, who is probably the most practical authority in the State, and he heartily indorses it, as you will see by his letter. The inventor proposes to rush the manufacture of them extensively, and, all things considered, it seems worthy of notice.

We requested Mr. Whitman, our special assistant in Minnesota, to see the pan tried; he did so, and found it to work well, though it accomplishes nothing more than the tar-pan, and, on account of being more expensive at first cost, was not so generally used. The pan has, we believe, been patented, and can be built for $6.

Under the present head may be mentioned the method that has been and may be in future adopted, under peculiar and favorable circumstances, of driving the insects into streams and catching them, as they float down, in sacks; and, finally, the use of hand-nets, such as entomologists ordinarily use in collecting and catching winged insects. This method is strongly advocated by Gerstäcker, Körte, and other European writers, and may be employed with advantage in a small way with us where special crops are to be cleared that would be injured by other methods. A simple net, such as that herewith illustrated (Pl. XII, Fig. 4), may be cheaply constructed by any tinsmith; the only material required being a piece of stout wire, a hollow tin tube in which to solder the two ends, and a piece of cotton or linen cloth, a wooden handle of any desired length being inserted in the non-soldered end of the tube.

(5) Use of Destructive Agents—We had a number of experiments made with different insecticide mixtures in 1876 and 1877, and the results are given in detail in the first report of the Commission. The only substance which indicated possible results of value was Paris green. Mixed with twenty to thirty parts of flour it was sprinkled on the ground, and many locusts were attracted to and destroyed by it. This mode, however, can not be compared with many of those already described. Its use against the young locusts is practically of little value, because of the excessive numbers in which they usually occur. Broadcast spraying of any crop, using, to be effective, Paris green or London purple in the proportion of 1 pound to 150 or 200 gallons of water, will be useful where spraying apparatus is at hand, but it will hardly pay to construct such an apparatus for this purpose alone, in view of the cheaper remedies just described.

THE PROTECTION OF FRUIT TREES.

The best means of protecting fruit and shade trees deserves separate consideration. Where the trunks are smooth and perpendicular they may be protected by whitewashing. The lime crumbles under the feet of the insects as they attempt to climb, and prevents their getting up. By their persistent efforts, however, they gradually wear off the lime and reach a higher point each day, so that the whitewashing must be often

repeated. Trees with short, rough trunks, or which lean, are not very well protected in this way. A strip of smooth, bright tin answers even better for the same purpose. A strip 3 or 4 inches wide brought around and tacked to a smooth tree will protect it, while on rougher trees a piece of old rope may first be tacked around the tree and the tin tacked to it, so as to leave a portion both above and below. Passages between the tin and rope, or the rope and tree can then be blocked by filling the upper area between tin and tree with earth. The tin must be high enough from the ground to prevent the 'hoppers from jumping from the latter beyond it, and the trunk below the tin, where the insects collect, should be covered with some coal tar or poisonous substances to prevent girdling. This is more especially necessary with small trees, and coal tar will answer as such preventives.

One of the cheapest and simplest modes is to encircle the tree with cotton batting, in which the insects will entangle their feet and thus be more or less obstructed. Strips of paper covered with tar; stiff paper tied on so as to slope roof-fashion; strips of glazed wall paper, and thick coatings of soft soap, have been used with varying success; but no estoppel equals the bright tin. The others require constant watching and removal, and in all cases coming under our observation some insects would get into the trees, so as to require the daily shaking of these morning and evening. This will sometimes have to be done, when the bulk of the insects have become fledged, even where tin is used, for a certain proportion of the insects will then fly into the trees. They do most damage during the night, and care should be had that the trees be unloaded of their voracious freight just before dark.

Mr. George Gibbs, of Holden, Missouri, found that the whitewash was rendered still more effectual by adding one-half pint of turpentine to the pailful.

DESTRUCTION OF THE WINGED INSECTS.

The complete destruction of the winged insects, when they swoop down upon a country in prodigious swarms, is impossible. Man is powerless before the mighty host. Special plants, or small tracts of vegetation may be saved by perseveringly driving the insects off, or keeping them off by means of smudges, as the locusts avoid smoke; or by rattling or tinkling noises constantly kept up. Long ropes perseveringly dragged over a grain field have been used to good advantage.

Of the different contrivances already described for the destruction of the unfledged locusts, those intended for bagging and catching are the most effectual against the winged individuals, great numbers of which may be caught, especially at morn and eve, and late in the autumn. At such times many may also be crushed. These winged insects are more to be dreaded in the northern than in the southern portion of the locust area, for in this last the small grains are always harvested before the advent of the pests, and Indian corn is the staple that suffers. The ex-

perience of Minnesota and Dakota farmers teaches that the injury from the winged locusts is best avoided by growing such crops as will mature early. Reports were current in 1876 in Texas that farmers near Calvert had destroyed great quantities of the winged insects by fires lighted at night. We had on several occasions witnessed swarms of locusts driven before a prairie fire, and our general experience of locust habits at night forbade belief in the reports, and we requested one of our correspondents to inquire into the matter, with the following result:

I took pains to trace up, while in Texas, the report that the *spretus* was attracted by a blaze. I found it, of course, baseless, though it had attained very respectable proportions.—(J. T. Moulton, jr.)

Moderate success has been had with smudging as a means of warding off the winged swarms. The best method is to start a fire which burns with insufficient access of air, and which is made, if possible, of materials which, while burning, will give off, besides the dense smoke due to incomplete combustion, unoxidized products of distillation which in themselves are noxious (*e. g.*, buffalo chips, straw, and coal tar, etc.). The smoke and fumes from such a fire will prevent the locusts from alighting and swerve them from their course. Mr. S. T. Kelsey succeeded in saving many of his young forest trees in Kansas, in 1874, by perseveringly smudging and smoking them. He gives his experience in the following words, in the *Kansas Farmer*, August 26, 1874:

At first we tried building fires on the ground, but it was not successful. The smoke would not go where we wanted it to. We then tried taking a bunch of hay and holding it between sticks, set fire to it, and then, passing through the field on the windward side, held it so that the smoke would strike the grasshoppers. We would soon have a cloud of 'hoppers on the wing, and, by following it up, would, in a short time, clear the field. We have thus far saved everything that was not destroyed when we commenced fighting them; and while I do not give this as an infallible remedy, not having tried it sufficiently, yet it does seem to me, from what I have seen of it, that one good, active man, who would attend right to it, could protect a 20-acre field or a large orchard. But to be successful one must attend strictly to business.

The great difficulty experienced in making the smudging successful is in the inconstancy of the winds, as a sudden change in wind direction may render much previous labor unavailing. Mr. W. D. Arnett, of Bear Creek, Colorado, who has given a good deal of attention to the practical means to be employed against locusts, has endeavored to meet the difficulty by using a portable iron bucket as a fire receptacle. A large sheet-iron bucket is fitted with a perforated tube, arranged across its bottom, open at one end to admit air, and there provided with a valve to regulate the admission of air. A perforated cover, hinged to the bucket, and a handle to carry it by, complete the arrangement. Filled with some substance which burns imperfectly, such as buffalo chips and a little coal tar, and with the cover shut, an amount of air insufficient for complete combustion is admitted through the valved tube at the bottom, and the dense smoke comes out through the holes in the cover.

The burning of old bones has been tried, but found to be no more effect-

ive than other slow combustibles. The use of smoke will be effectual in proportion as farmers combine together and produce it simultaneously over extended areas.

DIVERSIFIED AGRICULTURE.

There is nothing surer than that the destitution in western Missouri and eastern Kansas, in 1874–'75, was fully as much owing to the previous ravages of the Chinch Bug as to those of this locust. The Chinch Bug is an annual and increasing trouble; the locust only a periodical one. Now, the regions indicated are, agriculturally, the richest in those two states, and, for that matter, can scarcely be surpassed in the entire country. Consisting of high, rolling prairie, interspersed, as a rule, with an abundance of good timber, this area produces a very large amount of corn and stock. Of cultivated crops, corn is the staple, and, with a most generous soil, it has become the fashion to plant and cultivate little else, year after year, on the same ground. The corn-fields alternate more or less with pastures, and there is just enough small grain to breed and nourish the first brood of chinch-bugs which pass into the corn at harvest time and which scatter over the country by breeding and harboring in the corn-fields. Not to mention the different means to be employed in counteracting the ravages of this insect, a diversified agriculture is undoubtedly one of the most effectual. It must necessarily follow that the more extensively any given crop is cultivated to the exclusion of other crops the more will the peculiar insects which depredate upon it become unduly and injuriously abundant. The chinch-bug is confined in its depredations to the grasses and cereals. Alternate your timothy, wheat, barley, corn, etc., upon which it flourishes, with any of the numerous crops on which it can not flourish, and you very materially affect its power for harm. A crop of corn or wheat grown on a piece of land entirely free from chinch-bugs will not suffer to the same extent as a crop grown on land where the insects have been breeding and harboring. This fact is becoming partially recognized, and already hemp, flax, and castor-beans are to some extent cultivated in the States mentioned. But there are many other valuable roots and forage plants that may yet be introduced and grown as field crops.

Governor Pillsbury, of Minnesota, has a few pertinent remarks on this subject in one of his annual messages. He says:

> In my former messages I took occasion to urge upon farmers a greater diversification of their crops. The present tendency, I fear, is toward an aggravation rather than a correction of the evil referred to. Stimulated by recent heavy crops, land hunters have a passion for immense tracts and great wheat-farms. While the cultivation of our idle lands is always desirable, this pursuit of a single branch of farming is to be lamented. And I fear that the expectations of great profits of many inexperienced persons who are drawn into the movement by excitement is doomed to disappointment. A wiser course is to look to many sources of profit rather than to one. There is no better country than ours for the raising of stock. Our wool, beef, butter, and cheese are unsurpassed. With the production of these, wheat-growing alternates

admirably to the advantage of all the products. The continuous cultivation of a single crop must eventually exhaust the soil of the constituents for its profitable growth, while it is well known that the finest wheat crops were raised the past year on worn-out and abandoned grain-fields which had been resuscitated by a couple of years' rest in grass. It seems almost culpable to import corn, hogs, beans, and other products which can be grown here to perfection.

What Governor Pillsbury says of Minnesota is equally true of a very large portion of the country subject to locust injury. The advantage of growing more stock is especially obvious in some sections, not only as a means of best utilizing the surplus corn, but to avoid sweeping disaster; for when the locusts are so thick as to entirely sweep off cultivated crops, the wild prairie-grass is seldom so badly affected that it will not support stock.

LEGISLATION.

Too much stress can not be laid on the advantage of coöperation and concert of action, and legislation both to induce and oblige action is important. In every community there are those who persist in doing nothing to prevent locust injury. These indifferents frequently bring ruin not only upon themselves but upon more persevering neighbors, and any law will prove beneficial that will oblige every able-bodied man to work one or more days, either in the fall in destroying the eggs, or in the spring in killing the young insects, whenever the township trustees, at the request of a given number of citizens of the township, may call them to such work under special provisions similar to those of existing road laws.

In reference to bounty laws, the experience of Minnesota, where they were in force in some counties in 1875, is valuable, and the State commissioners did not hesitate to recommend the system after the county trials, imperfect as they were and commenced as they were, in most cases, too late in the season. It was clearly shown that in one township $30,000 worth of crops was saved by an expenditure of $6,000. Nicollet County paid $25,053 for 25,053 bushels of locusts, but the price paid by other counties was higher; in fact, much too high. In 1877 the bounty system was less effective, and indeed proved more or less a failure. "As a means of defense," writes Mr. Whitman, "it would have proved useless in some cases and needless in others; as a matter of relief or reimbursement for injury it would have gone in a large measure to help those who are already repaid by an abundant harvest."

Governor Pillsbury, in his annual message for 1877, speaks of the Minnesota bounty law, published further on, in the following rather severe terms:

These acts were approved by me with much reluctance, and not until I had strenuously but unavailingly endeavored to influence a correction in the act first named of what I deemed ill-advised provisions of a serious character. Prior to any movement for the practical operation of these laws, I received numerous statements from authoritative sources in all quarters of the infested regions, remonstrating against

the appointment of measurers, as contemplated, on the ground that owing to the incalculable numbers of the insects the provision requiring the counties to pay all bounties in excess of the proposed State appropriation of $100,000 would virtually bankrupt the afflicted counties. I therefore deemed it proper to defer action for further knowledge and consideration. Finding upon calculation that an equal distribution of the available fund would afford to each inhabitant of the infested localities an average of but forty cents, a sum too trifling in itself to induce additional efforts for the extermination of the pests, I became convinced that the enforcement of the bounty law would entail upon counties already impoverished by insect ravages a burden of debt which would prove more disastrous than the scourge it was intended to avert. I therefore, against the wishes of a few localities, but in compliance with a vast preponderance of petitions from the people directly interested, declined to make the appointments requisite for the practical operation of the law. The decision was justified by the result, for, in the absence of that concerted defense against the insects by ditches and other protective means dictated by experience, all efforts induced by the proposed State and county expenditures combined would certainly have been unavailing, especially where the destructive swarms were most dense and where protection was most needed from their ravages. The sum thus saved to the State remains intact, or rather the contemplated loan was not effected, the law in express terms specifying the exclusive object for which it was to be effected.

A good law, once enacted and on the statute book, may not be called into operation for many years, but would beyond all doubt serve an admirable purpose in the event of a locust invasion. The following are what we conceive should be the essential features of an efficient bounty law: (1) *The bounty should be paid out of the State treasury; or it should be graded and borne equally, one-third by the local townships, one-third by the county, and one-third by the State.* (2) *The bounty should be immediately available to those earning it.* (3) *The act should, so far as possible, tend to the destruction of the eggs.* (4) *After the eggs, the destruction of the newly-hatched locusts should be encouraged by the act.* A bushel of the newly hatched insects will contain thirty or more times as many individuals as will a bushel of the pupæ, and, moreover, their destruction prevents the subsequent injury. It would be folly to pay 60 cents a bushel for them later in the season when they are nearly full-grown and have done most of the harm they are capable of doing. The price, therefore, should vary with the season; and while, in latitude 39°, 75 cents or $1 should be offered in March, the price should diminish to 50 cents in April, 25 cents in May, and 10 cents in June. As the dates of hatching vary with the latitude, so the law should vary in the matter of dates, according to the requirements of each particular State. In addition to the foregoing requirements of such an act, every precaution should be taken to prevent fraud and dishonesty in obtaining the money.

The laws obliging proper labor will prove more beneficial to a community than the bounty laws, and the labor is best performed, first in destroying the eggs in the fall, and next in destroying the young insects after the bulk of them have hatched out in the spring.

In the more thinly settled parts of the country laws may be more or less ineffectual, so far as the general destruction of the insects is con-

cerned, though they will even there be one of the best means of relieving destitution; but in more thickly settled portions they will accomplish both results.

BRAN-ARSENIC MASH.

In 1885, Mr. Coquillett experimented with a mash composed of bran and arsenic on the devastating locust in the San Joaquin Valley, California, which was so successful that we quote his account in full.

A remedy that has been very successful in destroying locusts consists of a certain proportion of bran, arsenic, sugar, and water. These have been used in different proportions, but the one that appears to give the best results consists of one part by weight of arsenic, one of sugar, and six of bran, to which is added a sufficient quantity of water to make a wet mash.

This preparation is usually prepared in washtubs or half-barrels. One of these is filled about three-fourths full of dry bran, and to this is added about 5 pounds of arsenic, which is thoroughly stirred through the bran with a spade or shovel. Five pounds of sugar is next thrown into a pail, which is then filled with water and the sugar stirred until it is dissolved, when this sugar water is added to the bran and arsenic and the three well stirred, more water is added and the stirring continued until every portion of the mash becomes thoroughly saturated.

About a teaspoonful of this mash is placed at the root of each tree, shrub, or plant infested with locusts, dropping it in the shade when this can be done. In the case of low shrubs or plants nothing more need be done, as the locusts will find their way to the poison, but when large trees are treated the locusts should be jarred out of them, or be driven out with long poles.

I have known locusts to be killed by eating some of this mash that had been put out over a week previously. The poison works very slowly, and when put out early in the morning will show but little effect upon the locusts until quite late in the day. A Devastating Locust that I saw eating the mash at 9 o'clock in the forenoon was still alive at 6 in the evening, but was dead when next examined early the next morning.

Allowing a teaspoonful of this mash to each grape vine in the vineyard—the vines being 7 or 8 feet apart—this will require about 10 pounds of the dry bran (and arsenic and sugar in proportion) to each acre. The cost of the material will vary, but should not exceed 50 cents for each acre of grapevines, including cost of labor for mixing and applying it. For orchards the cost will be much less than this.

The addition of sugar to this mash is merely for the purpose of causing the arsenic to adhere to the particles of bran, and not for the purpose of increasing its attractiveness, since bran is more attractive to the locusts than sugar. This I have demonstrated to my own satisfaction. A quantity of sugar was placed upon the ground contiguous to an equal quantity of bran mash; when a locust came to the sugar he would eat a little of it, move on a short distance and again take a few bites of the sugar, and continue in this manner until he reached the mash, when he would settle down, eat his fill, and then move off. The locusts which came to the mash before reaching the sugar would, almost without exception, eat their fill of the mash and then walk away, but occasionally one would leave the mash and take a few bites of the sugar, only to return to the mash again. None of them eat their fill of the sugar, but always manifested an evident preference for the mash.

This mash was used upon about 300 acres of orchard and vineyard on the Buhach plantation, and about 2 weeks later scarcely a living locust was to be seen where they could have been counted by the hundred or even thousands before the poison had been applied, the ground in many places being literally covered with the dead bodies of the slain.

Several other parties also used this poisonous mash, and so far as I was able to learn, it gave entire satisfaction in every instance.

By exercising only ordinary precautions there need be no fear of endangering the lives of either man or any of the domestic animals in using this poisonous preparation. It should be mixed in a close room to prevent the arsenic from being blown about by the wind. There is no need of touching the arsenic or the mixture with the hands, as the mixing and distributing is accomplished by means of spades, shovels, wooden paddles, etc.

Of course this mixture should not be put out in places where poultry or any of the domestic animals can gain access to it. Upon the Buhach plantation were four greyhounds and several cats that were allowed to roam about the plantation where this mixture had been put out for the locusts; still, at the time that I left the plantation—about 4 weeks after the poisonous mixture had been put out—not one of them had been killed either by eating of the mixture itself or of the locusts that had been poisoned by it.

There were also several barnyard fowls upon this plantation, but not one of them was poisoned from having eaten locusts that may have found their way to the poultry range after having eaten of the poisonous mixture. Mr. Boynton, whose farm adjoins the Buhach plantation on the west, stated to me that many of the locusts which had eaten of the poisonous mixture would fall into an irrigating ditch that flowed through his poultry yard, and many of the locusts were thus carried within the reach of his fowls; still he was not aware that any of the latter had died from the effects of having eaten of the poisoned locusts.

In fact, I did not learn of a single instance where this mixture had caused the death of any person, nor of any domestic animal, although it was used very extensively in many parts of the San Joaquin Valley. Neither were the birds killed in any considerable numbers from having eaten either of the mixture itself or of the locusts that had been poisoned by it. During the 4 weeks following the putting out of this mixture upon about 300 acres of the Buhach plantation, I found only about half a dozen dead birds that had evidently met their death through the agency of this mixture; these consisted of three or four meadow larks, a bee-bird, and a field sparrow.

Rabbits and hares, or "jack rabbits," as they are commonly called, were destroyed in large numbers by this mixture. After the greater number of locusts upon the Buhach plantation had been destroyed the work of extermination was carried into a large patch of wild sunflowers adjoining the plantation on the north, and as one of the results, at least two dozen hares paid the penalty with their lives.

The four greyhounds belonging to the plantation were among these poisoned hares almost every day; still I never saw one of them attempt to feed upon the poisoned hares; certain it is that not one of them met his death from this cause.

As the mixture is saturated with water before it is put among the plants infested with locusts, there is no danger of its being blown about by the wind; and there is also very little danger of its being deposited upon the fruit by the feet of birds and insects that may have alighted upon the mixture and afterwards flown to and alighted upon the fruit. As the mixture becomes dry its particles adhere together, forming a solid mass which could not be blown about by the wind.

I have never seen this poisonous mixture used in grain fields, but know of no reason why it would not prove very effectual in such fields. Great care should be exercised in using it in alfalfa fields, but if it were placed upon small pieces of boards it could doubtless be used with entire safety in such fields; but of course it would not be safe to pasture any animal in such fields, even after the poison had been removed.

EXPLANATION TO PLATE I.

FIG. 1.—ROCKY MOUNTAIN LOCUST: *a*, *a*, *a*, female in different positions, ovipositing; *b*, egg-pod extracted from ground, with the end broken open; *c*, a few eggs lying loose on the ground; *d*, *e*, show the earth partially removed, to illustrate an egg-mass already in place and one being placed; *f*, shows where such a mass has been covered up. (After Riley.)

FIG. 2.—ROCKY MOUNTAIN LOCUST: Anal characters of female, showing horny valves. (After Riley.)

FIG. 3.—ROCKY MOUNTAIN LOCUST: Enlarged end of body of female, showing the method of oviposition; *j*, the oviduct; *g*, the egg-guide, and egg issuing from horny valves. (After Riley.)

FIG. 4.—EGG OF ROCKY MOUNTAIN LOCUST: *a*, showing sculpture of outer shell; *b*, the same, very highly magnified; *c*, the inner shell just before hatching. (After Riley).

FIG. 5.—EGG-MASS OF ROCKY MOUNTAIN LOCUST: *a*, from the side, within burrow; *b*, from beneath; *c*, from above, enlarged. (After Riley.)

FIG. 6.—THE DRUM LOCUST-CRUSHER: Plan view.

FIG. 7.—THE DRUM LOCUST-CRUSHER: Vertical section.

EXPLANATION TO PLATE II.

FIG. 1.—THE SIMPSON LOCUST-CRUSHER: Perspective view.

FIG. 2.—THE SIMPSON LOCUST-CRUSHER: Sectional view.

FIG. 3.—THE SIMPSON LOCUST-CRUSHER: Sectional view, when ready to remove the insects.

FIG. 4.—THE HOOS LOCUST-CRUSHER: Top view.

FIG. 5.—THE HOOS LOCUST-CRUSHER: Vertical section.

EXPLANATION TO PLATE III.

FIG. 1.—THE HOOS LOCUST-CRUSHER: Side view.

FIG. 2.—THE HANSBERRY LOCUST-CRUSHER: Top view.

FIG. 3.—THE HANSBERRY LOCUST-CRUSHER: Front view.

FIG. 4.—THE HANSBERRY LOCUST-CRUSHER: Sectional view.

FIG. 5.—THE HANSBERRY LOCUST-CRUSHER: Slide attachment.

FIG. 6.—THE KENWORTHY LOCUST-MACHINE: Plan view.

FIG. 7.—THE KENWORTHY LOCUST-MACHINE: Side view.

EXPLANATION TO PLATE IV.

FIG. 1. THE PETELER LOCUST-CRUSHING MACHINE: Front view.

EXPLANATION TO PLATE V.

FIG. 1.—THE PETELER LOCUST-CRUSHING MACHINE: Side view.

FIG. 2.—THE KING SUCTION MACHINE: Front view.

EXPLANATION TO PLATE VI.

FIG. 1.—THE KING SUCTION MACHINE: Side view, in operation.

EXPLANATION TO PLATE VII.

FIG. 1.—THE CANFIELD COAL-OIL PAN: Perspective view.

FIG. 2.—THE CANFIELD COAL-OIL PAN: Longitudinal view.

FIG. 3.—THE ADAMS LOCUST-PAN.

EXPLANATION TO PLATE VIII.

FIG. 1.—THE PRICE OIL-PAN.
FIG. 2.—SIMPLE COAL-OIL PAN.
FIG. 3.—THE ANDERSON COAL-OIL CONTRIVANCE.

EXPLANATION TO PLATE IX.

FIG. 1.—THE ROBBINS COAL-TAR PAN.
FIG. 2.—THE FLORY LOCUST-MACHINE: Front view, in operation.
FIG. 3.—THE FLORY LOCUST-MACHINE: Side view of frame.

EXPLANATION TO PLATE X

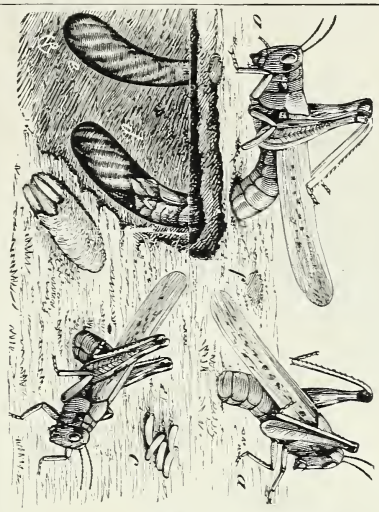
FIG. 1.—THE RILEY LOCUST-CATCHER.

EXPLANATION TO PLATE XI.

FIG. 1.—THE WILSON-RHODE LOCUST-CATCHER: Side view.
FIG. 2.—THE WILSON-RHODE LOCUST-CATCHER: Top view.
FIG. 3.—THE GODARD LOCUST-CATCHER: Plan view.
FIG. 4.—THE GODARD LOCUST-CATCHER: Vertical section.
FIG. 5.—THE GODARD LOCUST-CATCHER: End view of frame.
FIG. 6.—THE BENSON LOCUST-CATCHER: Plan view.
FIG. 7.—THE BENSON LOCUST-CATCHER: Vertical section.

EXPLANATION TO PLATE XII.

FIG. 1.—THE HUTCHINS LOCUST-CATCHER: Top view.
FIG. 2.—THE HUTCHINS LOCUST-CATCHER: Sectional view.
FIG. 3.—THE SYLVESTER LOCUST-CATCHER.



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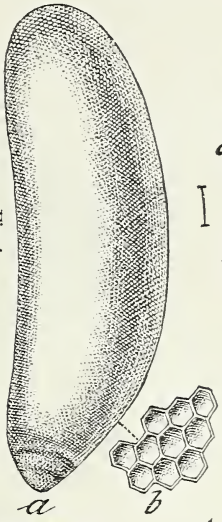

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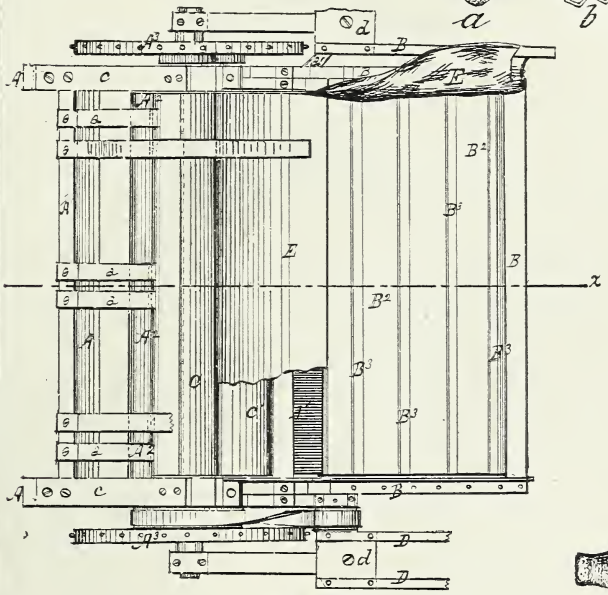

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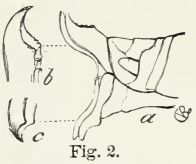

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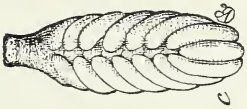

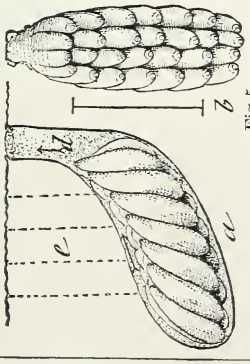

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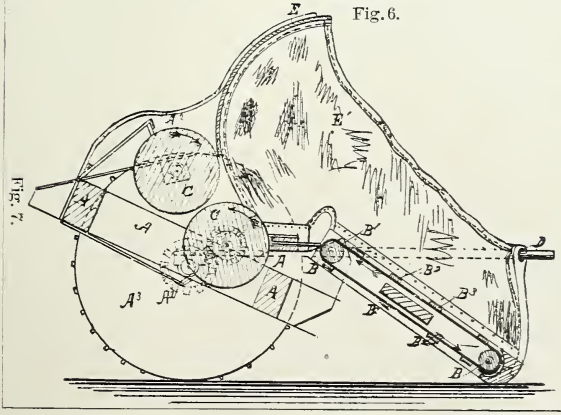

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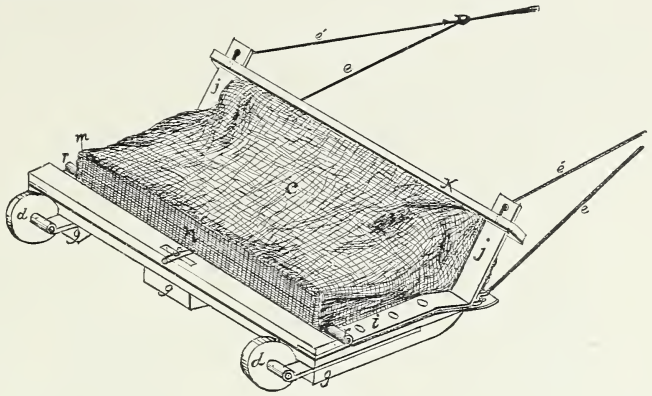

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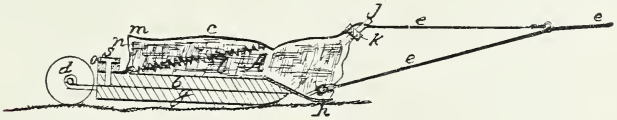

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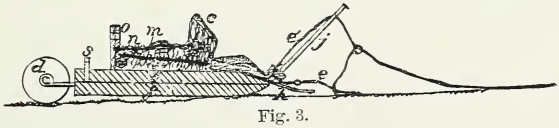

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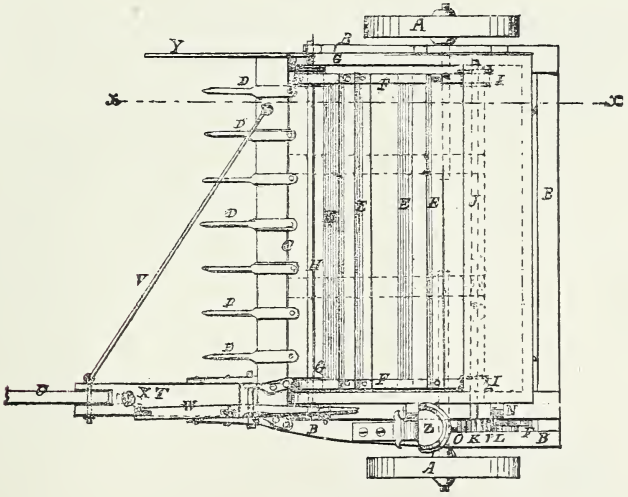

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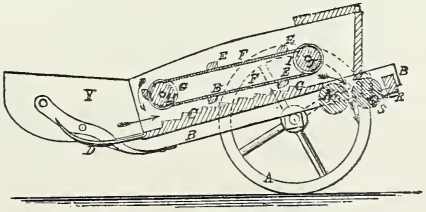

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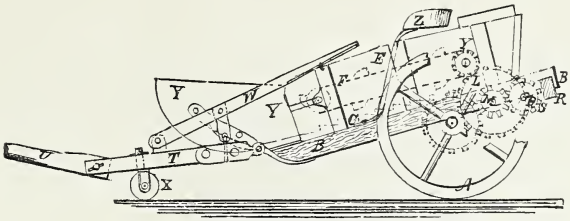

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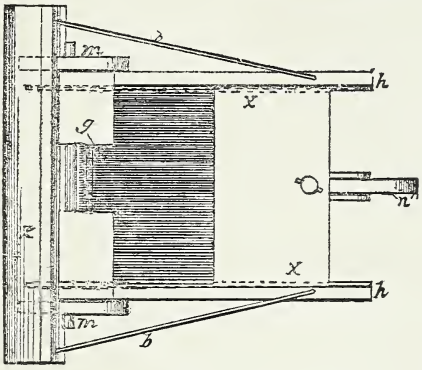

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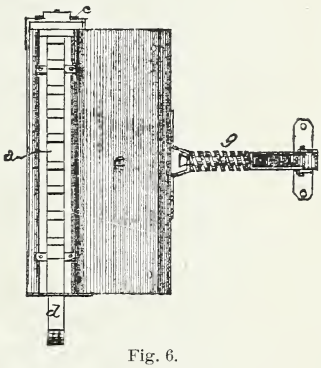

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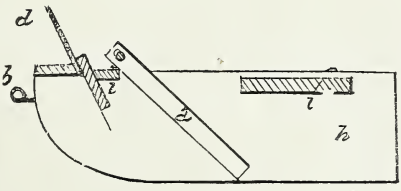

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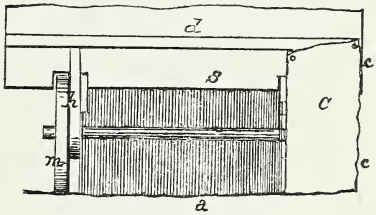

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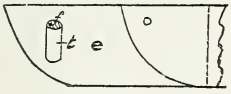

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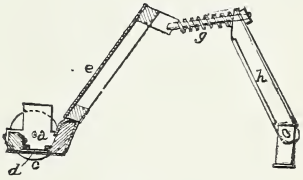

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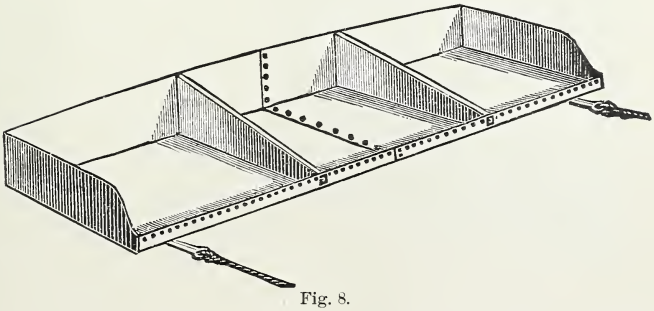

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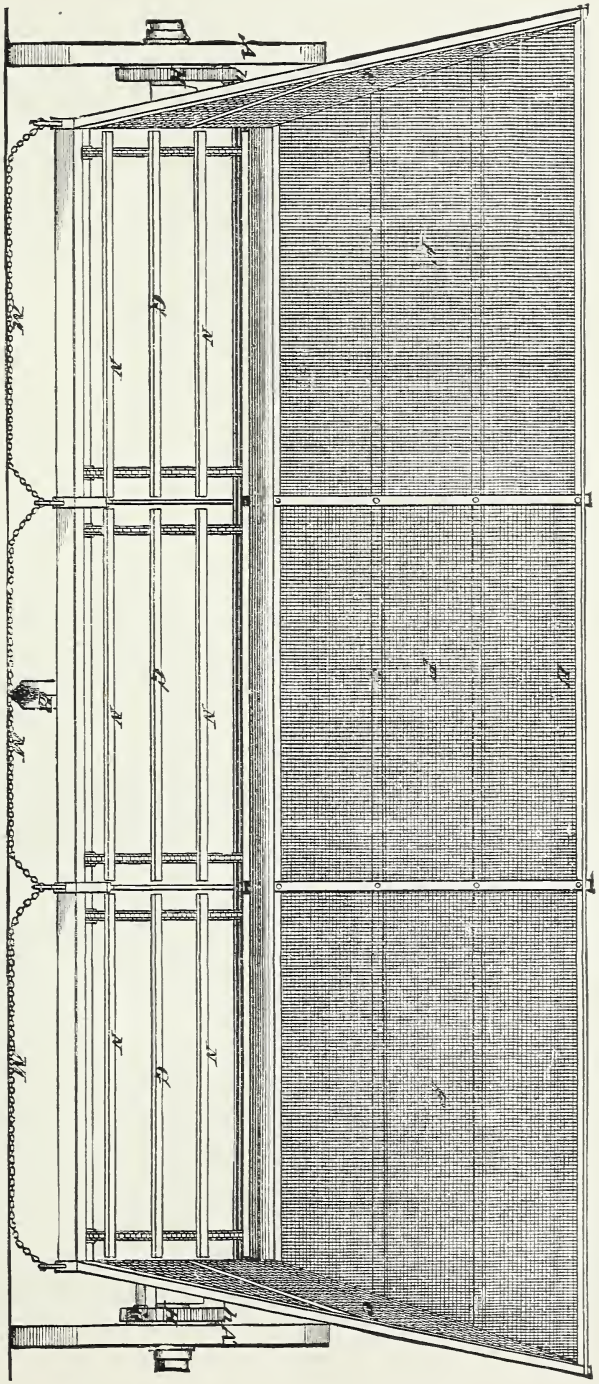

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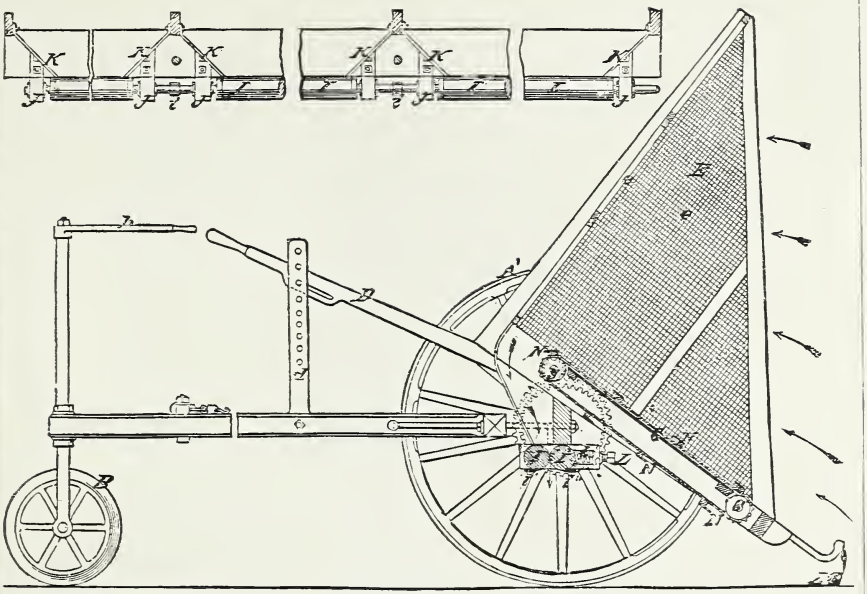

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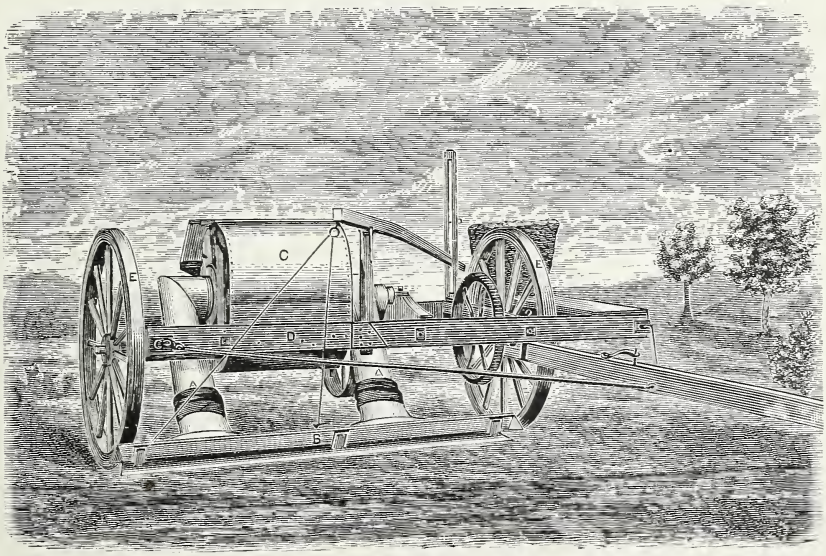

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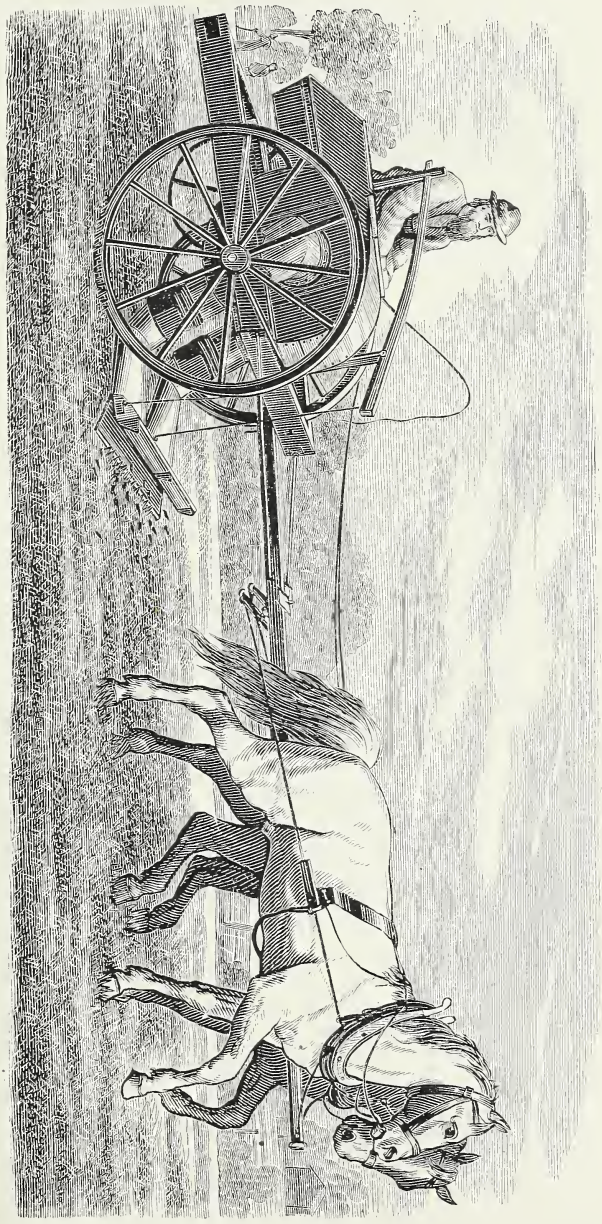

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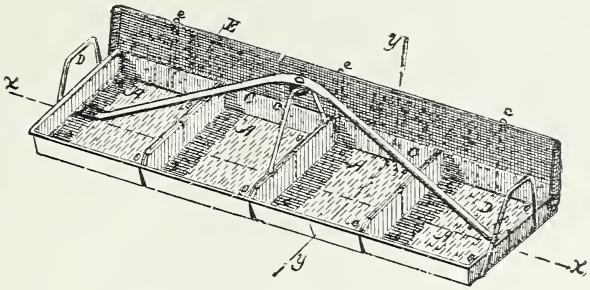

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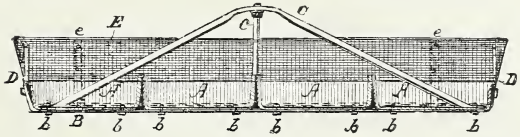

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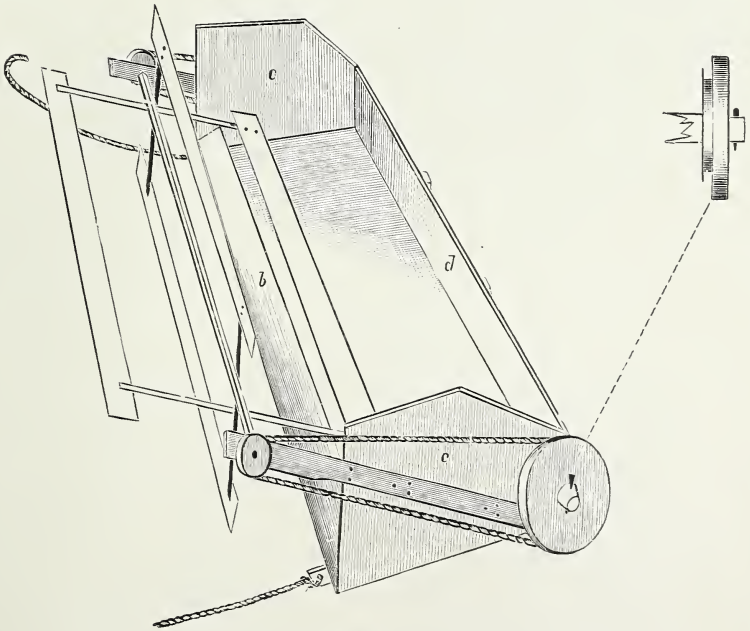

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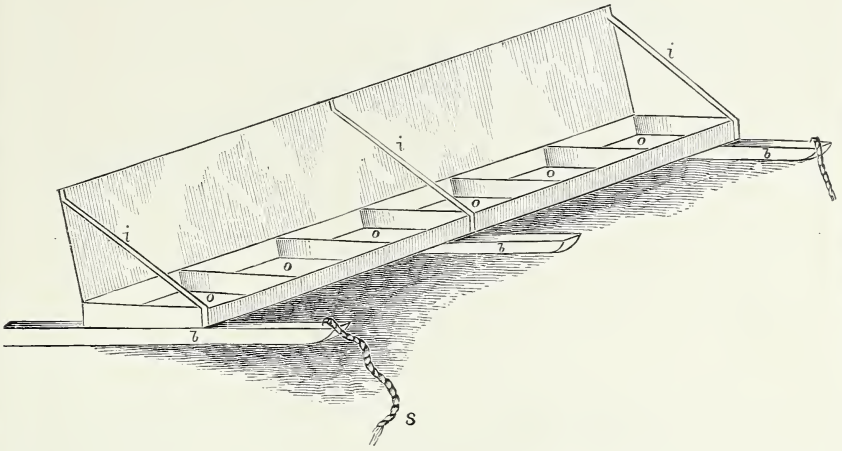

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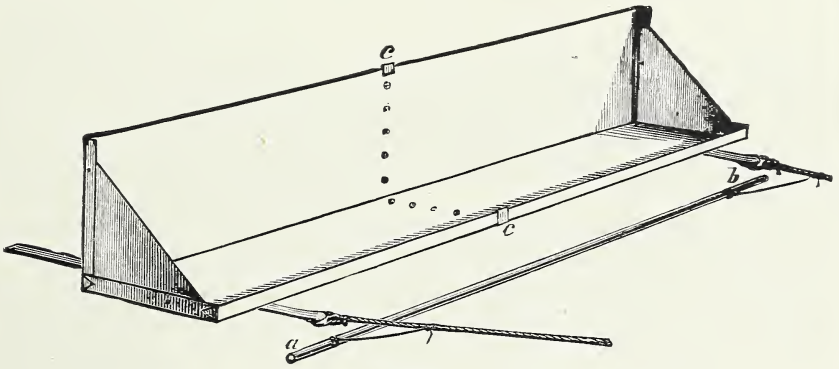

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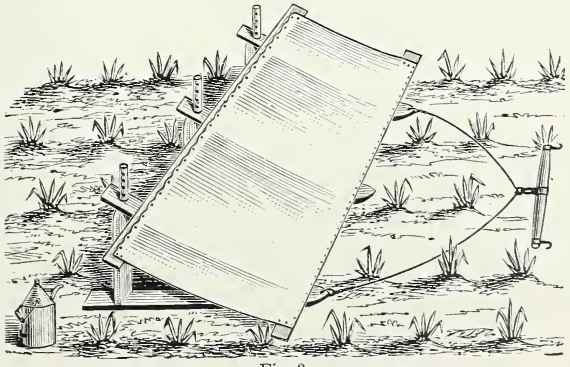

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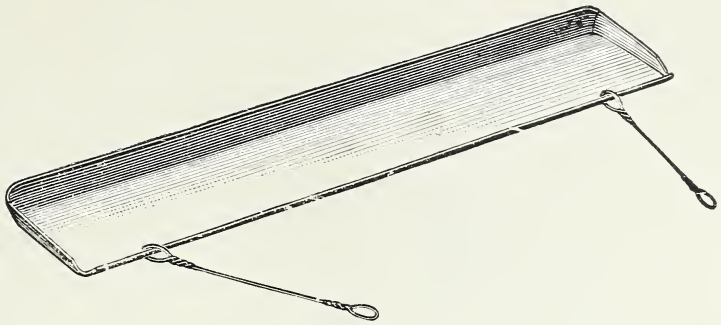

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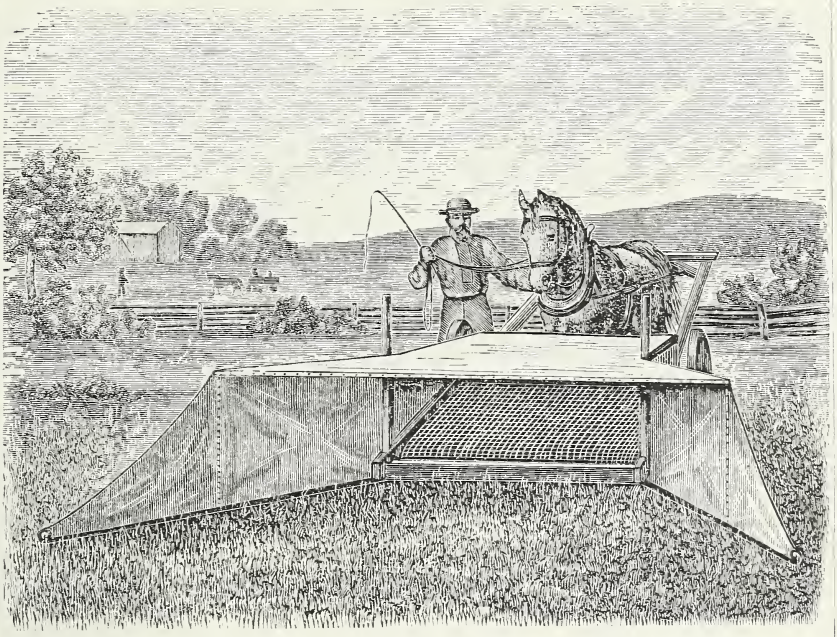

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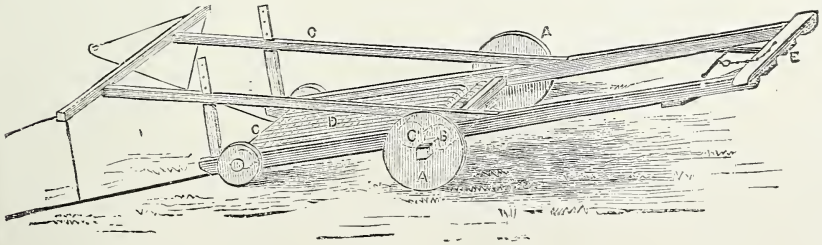

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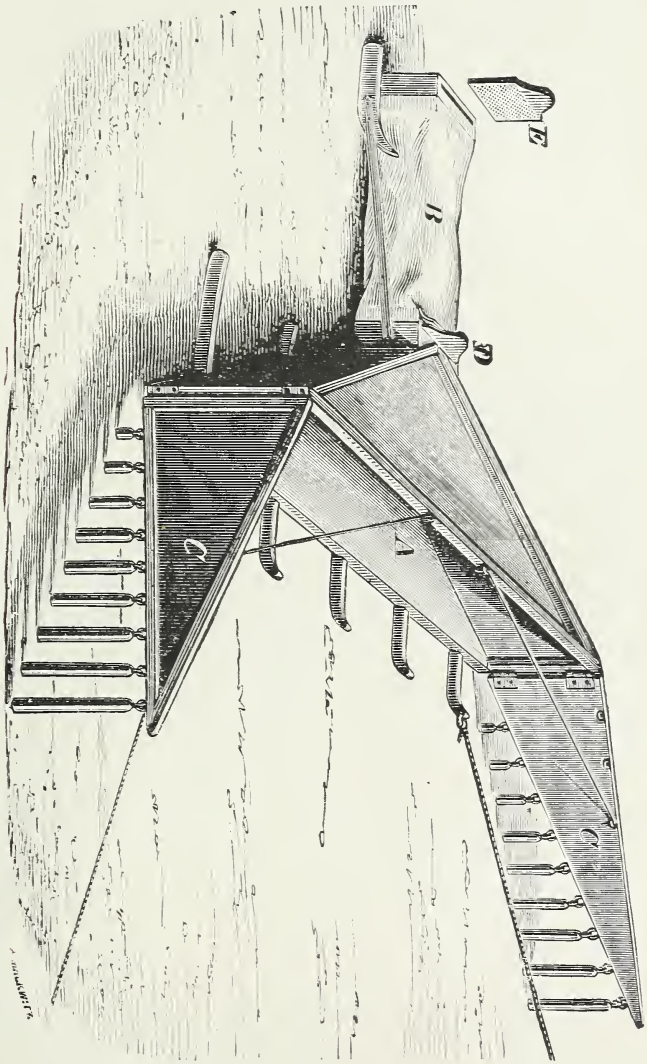

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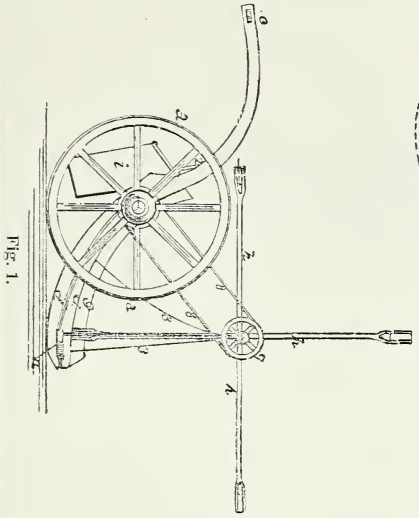

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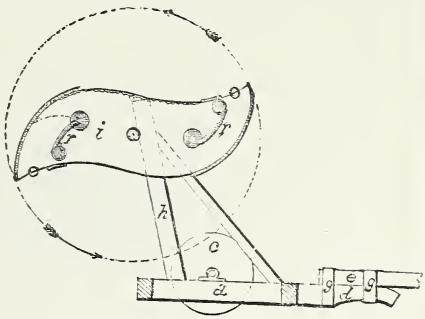

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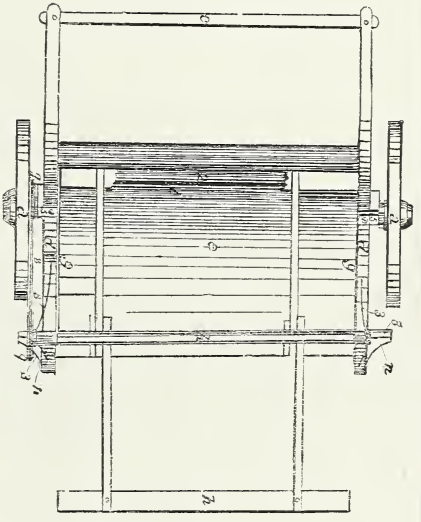

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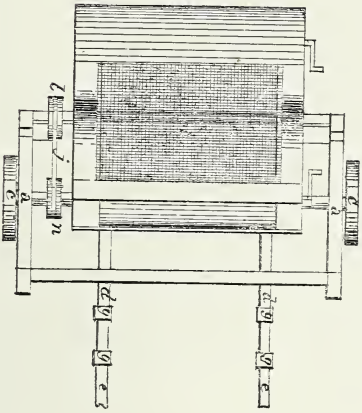

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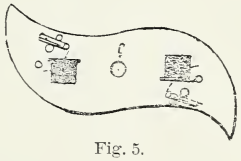

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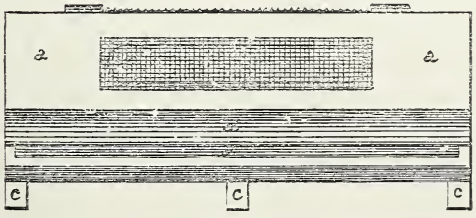

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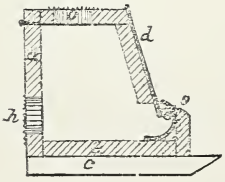

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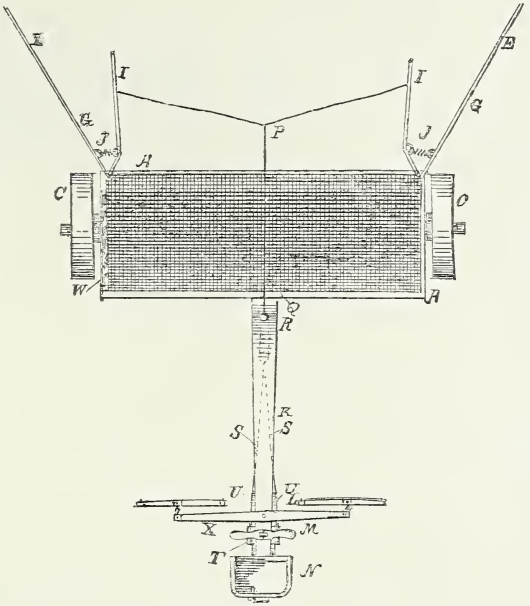

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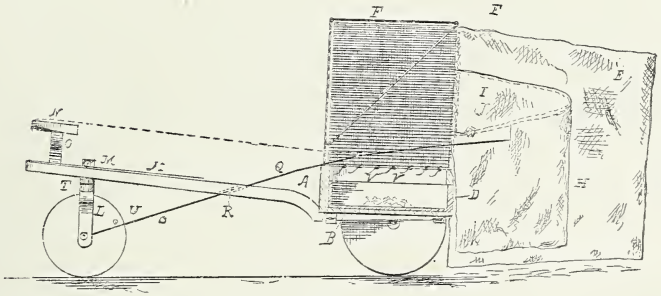

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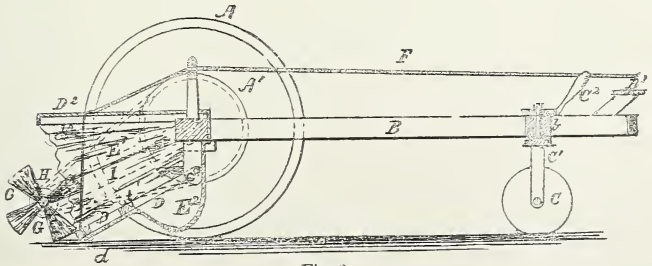

Fig. 3.